Progress Update

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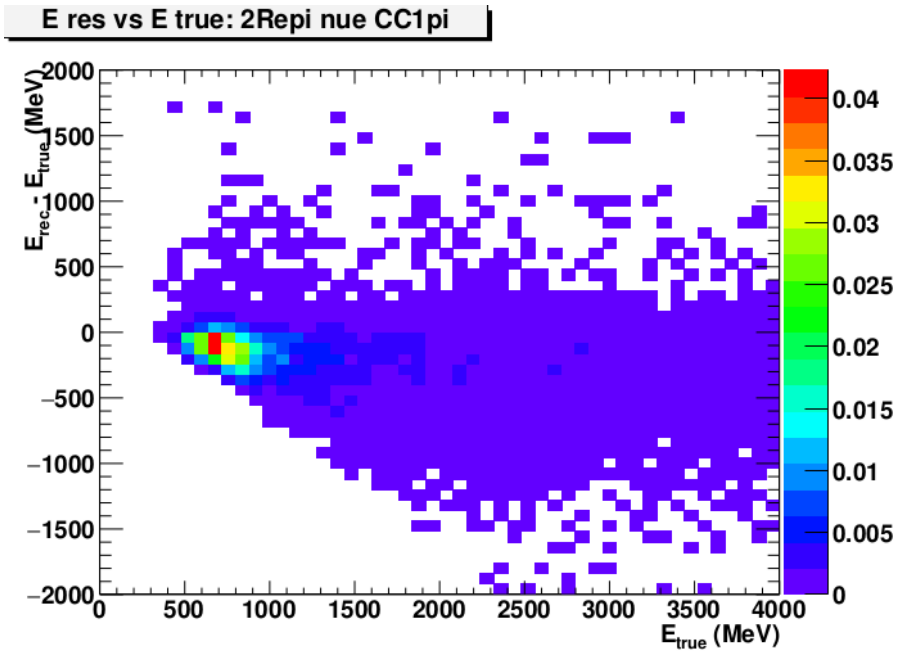
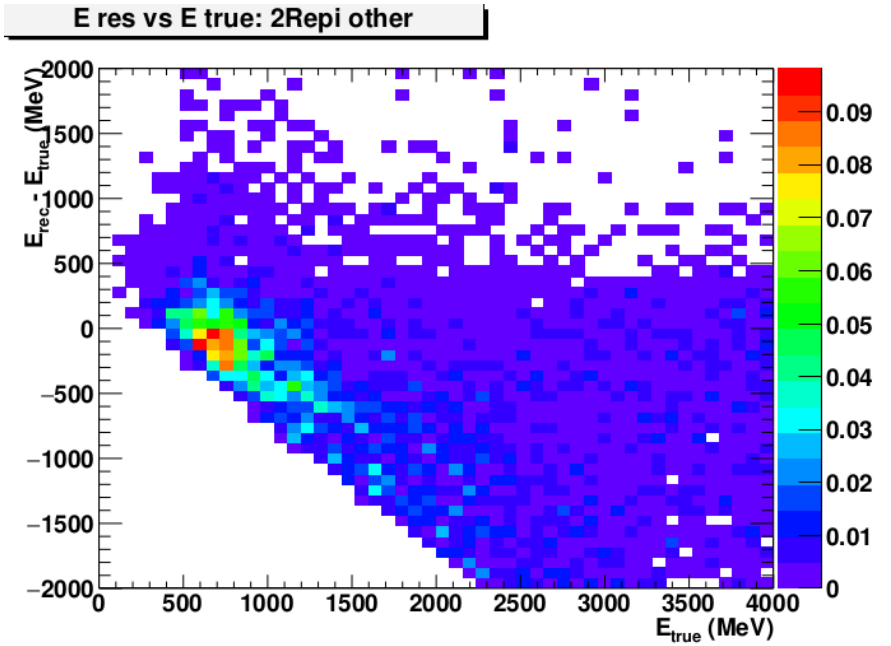
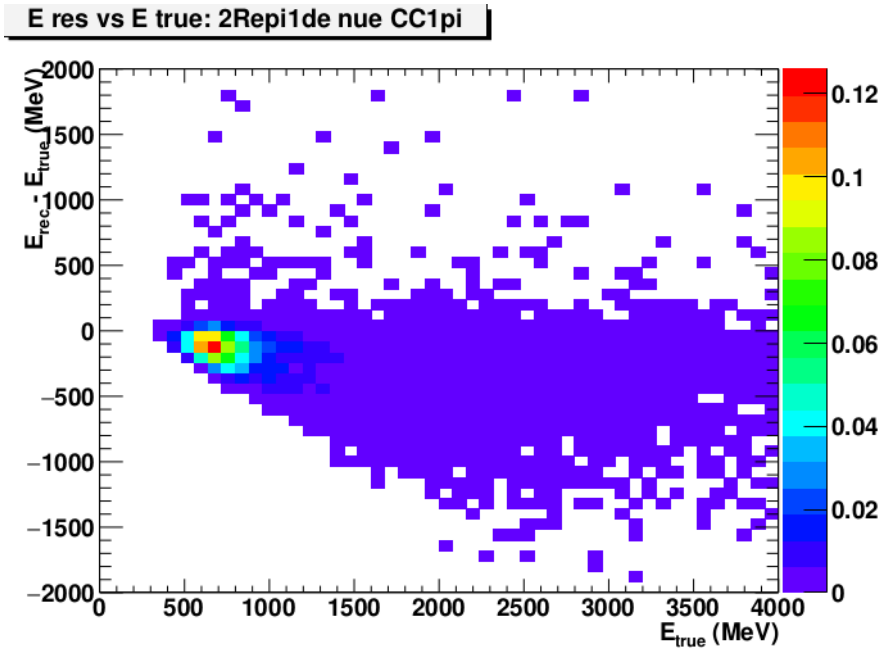
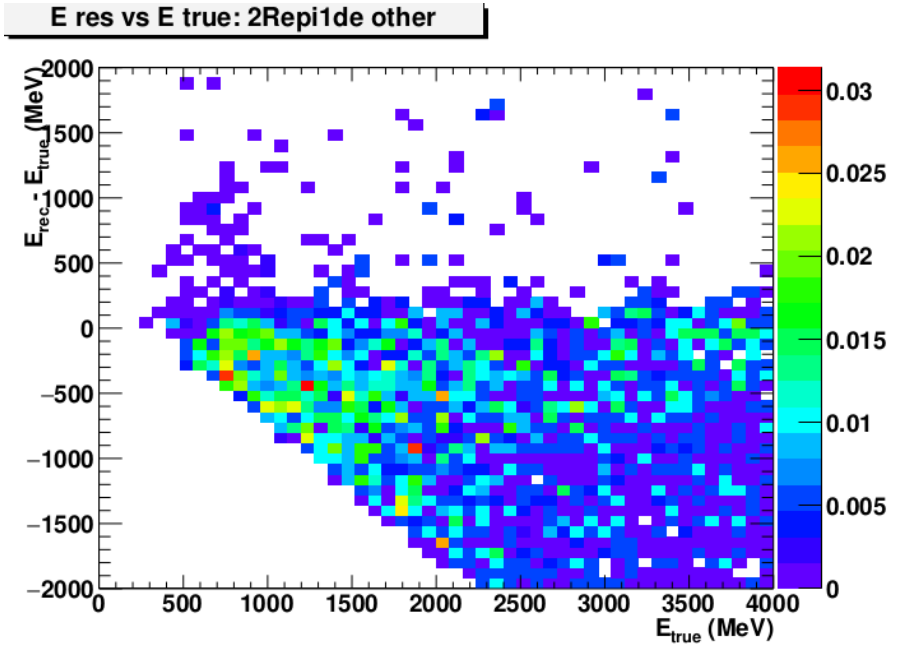
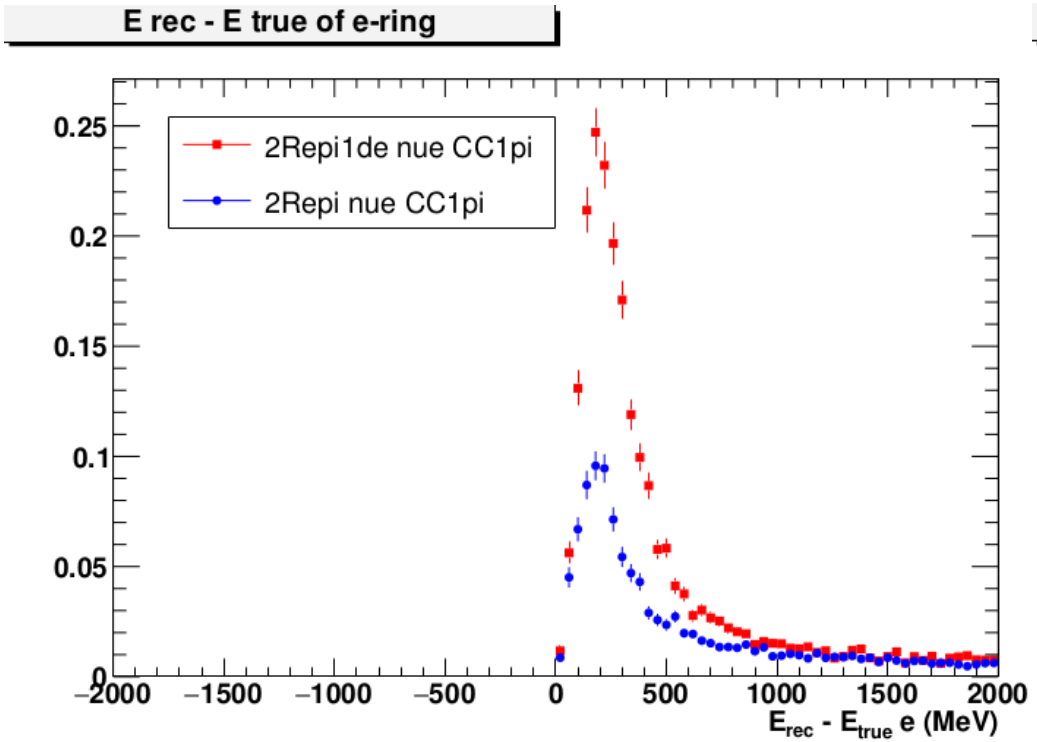
UofT Neutrino/DM Meeting
October 25, 2017

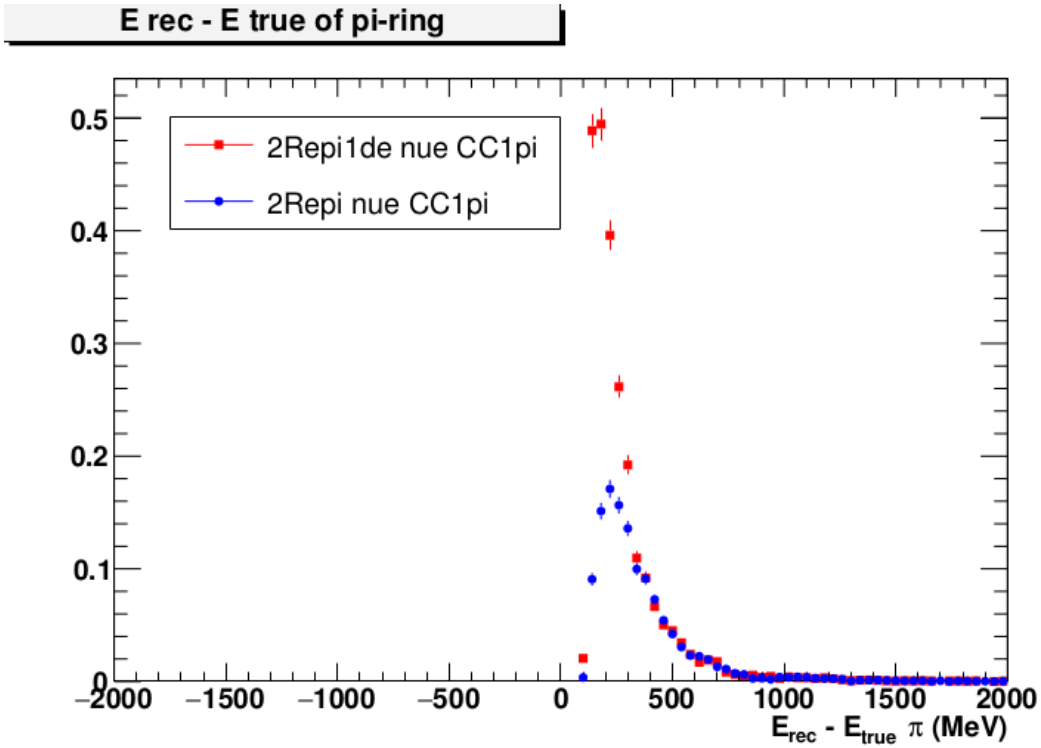

E res vs E true: 2Repi nue CC1pi
$E_{rec.} - E_{true}$ (MeV)
E_{true} (MeV)


E res vs E true: 2Repi other
$E_{rec.} - E_{true}$ (MeV)
E_{true} (MeV)


E res vs E true: 2Repi1de nue CC1pi
$E_{rec.} - E_{true}$ (MeV)
E_{true} (MeV)


E res vs E true: 2Repi1de other
$E_{rec.} - E_{true}$ (MeV)
E_{true} (MeV)





Something wrong in code?

```
if (int_mode==1 && (Is2repi_exp || Is2repi1de_exp)){ // if true CC1pi event, determine energy resolution of e and pi rings
  Erese = sqrt(0.511*0.511 + fqmrmom[0][iering]*fqmrmom[0][iering]) - sqrt(0.511*0.511 + pnu[2]*pnu[2]);
  Erespi = sqrt(139.57*139.57 + fqmrmom[0][ipiring]*fqmrmom[0][ipiring]) - sqrt(139.57*139.57 + pnu[3]*pnu[3]);
}
```

Use NEWORK?

```
<NEWORK> ( vector list at neutrino interaction )

numnu          :  number of particle at neutrino interaction
               :  numnu=1    incoming neutrino
               :       2     target
               :       3     outgoing lepton
               :       4     outgoing target
               :     >=5     other particles
mode           :  interaction mode of neutrino, see neut/nemodsel.F
               :  +-1        CC quasi-elastic
               :  +-(11-13)  CC single pi from delta resonance
               :  +-16       CC coherent pi production
               :  +-21       CC multi pi production
               :  +-27       CC diffractive pion production
               :  +-(31-34)  NC single pi from delta resonance
               :  +-36       NC coherent pi
               :  +-41       NC multi pi production
               :  +-47       NC diffractive pion production
               :  +-(51,52)  NC elastic
ipnu(numnu)    :  particle code at neutrino interaction (P.D.G. code)
               :  ipnu(1)==12 nu-e    ipnu(1)==-12 nu-e-bar
               :  ipnu(1)==14 nu-mu   ipnu(1)==-14 nu-mu-bar
               :  ipnu(1)==16 nu-tau  ipnu(1)==-16 nu-tau-bar
pnu(numnu)     :  momentum at neutrino interaction (GeV/c)
dirnu(3,numnu) :  direction at neutrino interaction
```

Or loop through VCWORK?

```
<VCWORK> ( Copy of VECT and NEWORK primary stacks with additional information )

Npvc           : Number of primary (including intermediate) particles
Ipvc           : PDG particle code
Pvc            : 3-momentum of particle ( MeV/c )
Abspvc         : Absolute momentum of particle ( MeV/c )
Iorgvc         : Index of parent particle
Iflvc          : Flag for final fate of this particle
                   0 : DETERMINED LATER PROCEDURE
                   1 : DECAY TO OTHER PARTICLE
                   2 : ESCAPE FROM DETECTOR
                   3 : ABSORPTION
                   4 : CHARGE EXCHANGE
                   5 : STOP AND NOT CONSIDER IN M.C.
                   6 : E.M. SHOWER
                   7 : HADRON PRODUCTION
                   8 : QUASI-ELASTIC SCATTER
                   9 : FORWARD (ELASTIC-LIKE) SCATTER
Ichvc          : Flag to chase or not
                   0 : DO NOT CHASE
                   1 : CHASE
```

Testing some cuts

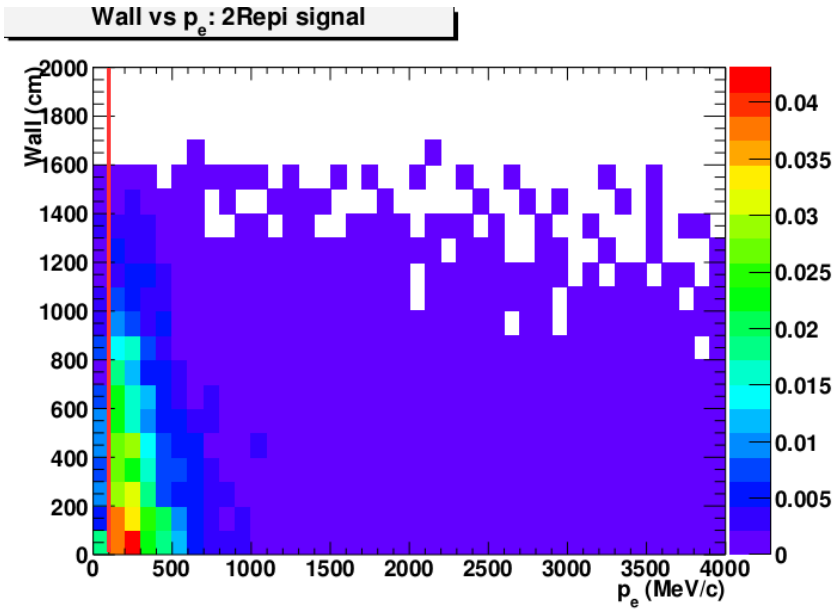
- Tried out a set of cuts based on looking at histograms (FHC, NH, dcp=0)

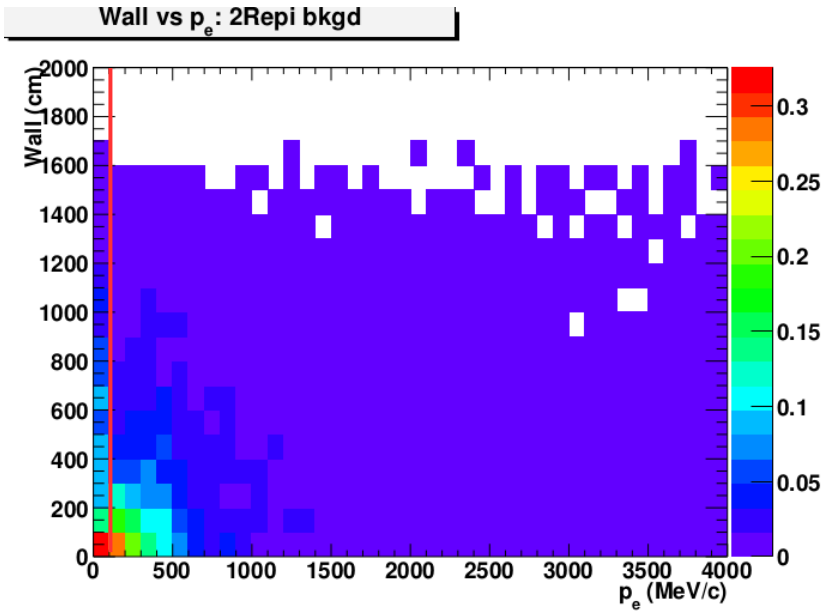
2Repi
FCFV
2 rings
epi-like
0 decay e
p_e > 100MeV
|p_e-p_pi| < 800MeV

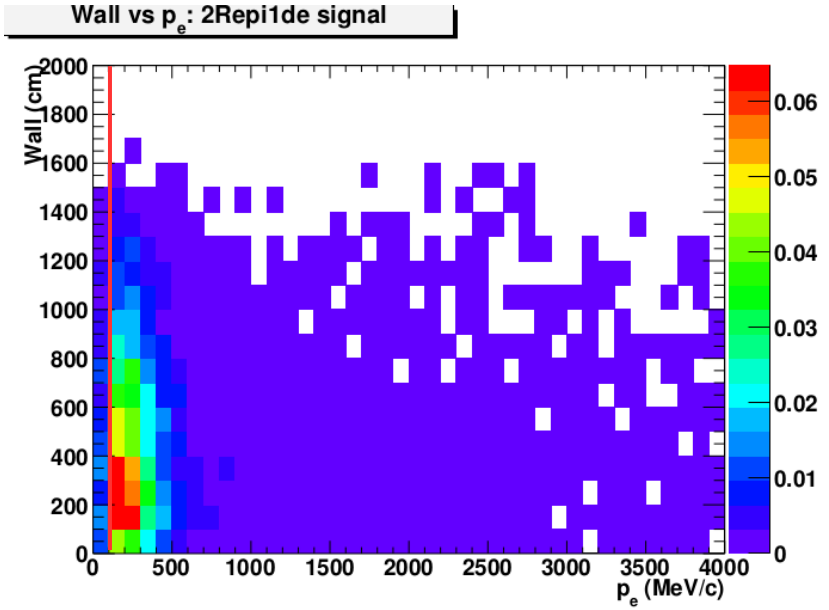
2Repi1de
FCFV
2 rings
epi-like
1 decay e
p_e > 100MeV
|p_e-p_pi| < 800MeV
d2se < 200cm

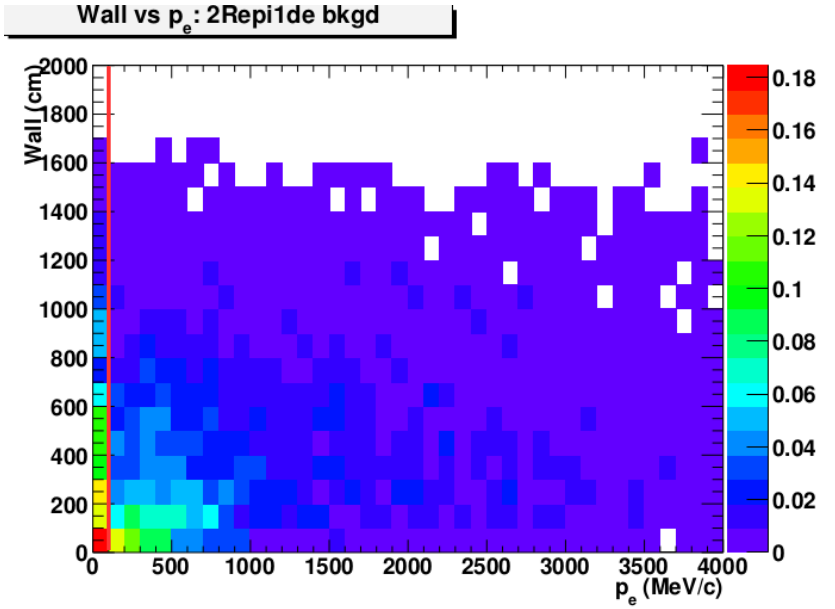
FCFV: evclass==1 && evis>30. && nhitac<16 && fqwall_2r>100.

p_e > 100 MeV

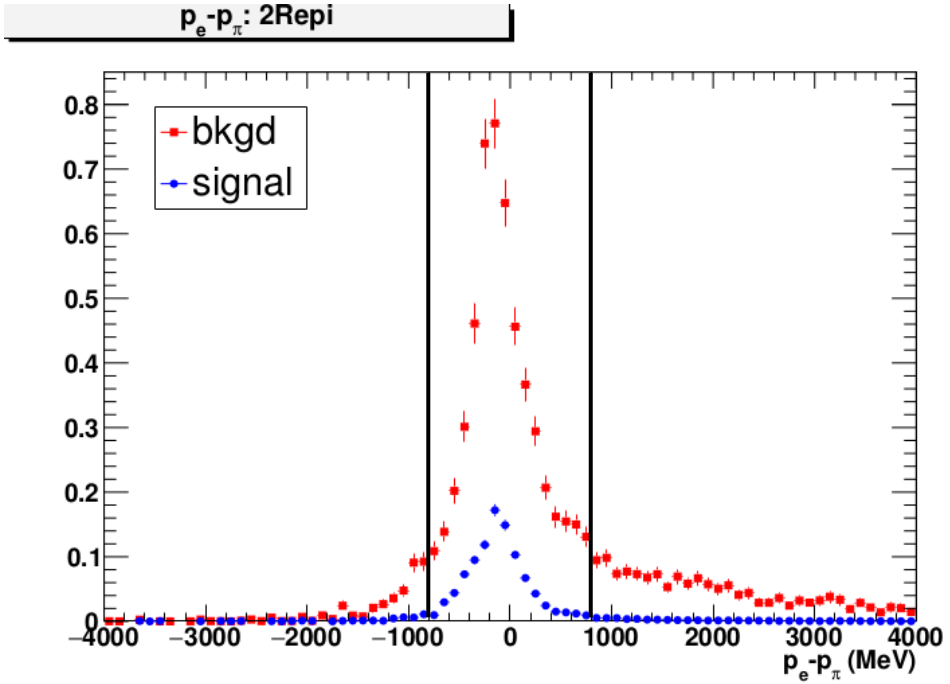

Wall vs p_e: 2Repi signal
Wall (cm)
p_e (MeV/c)

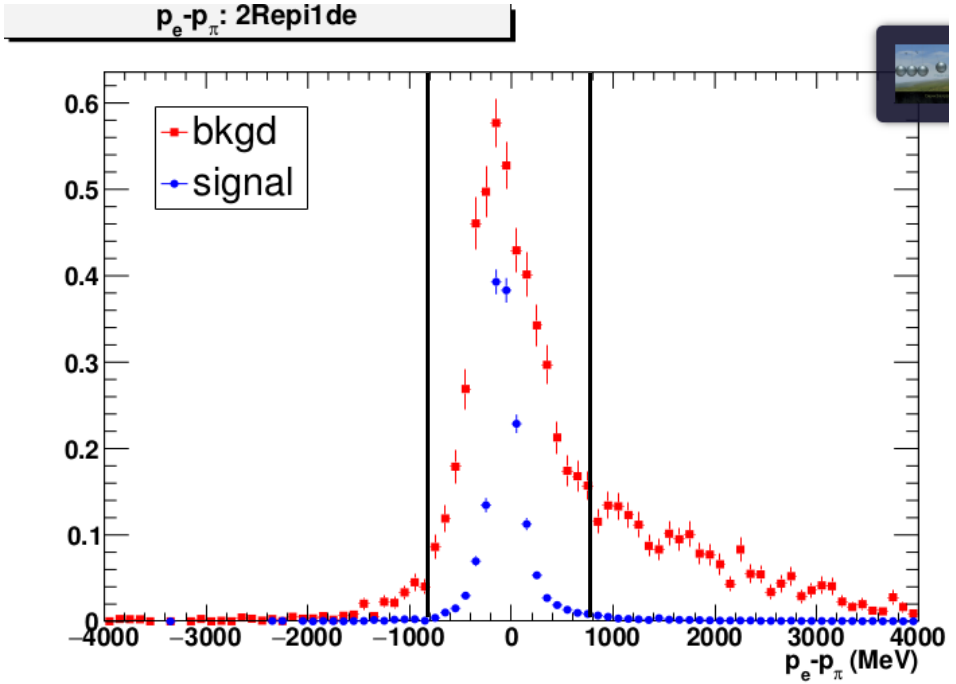

Wall vs p_e: 2Repi bkgd
Wall (cm)
p_e (MeV/c)


Wall vs p_e: 2Repi1de signal
Wall (cm)
p_e (MeV/c)

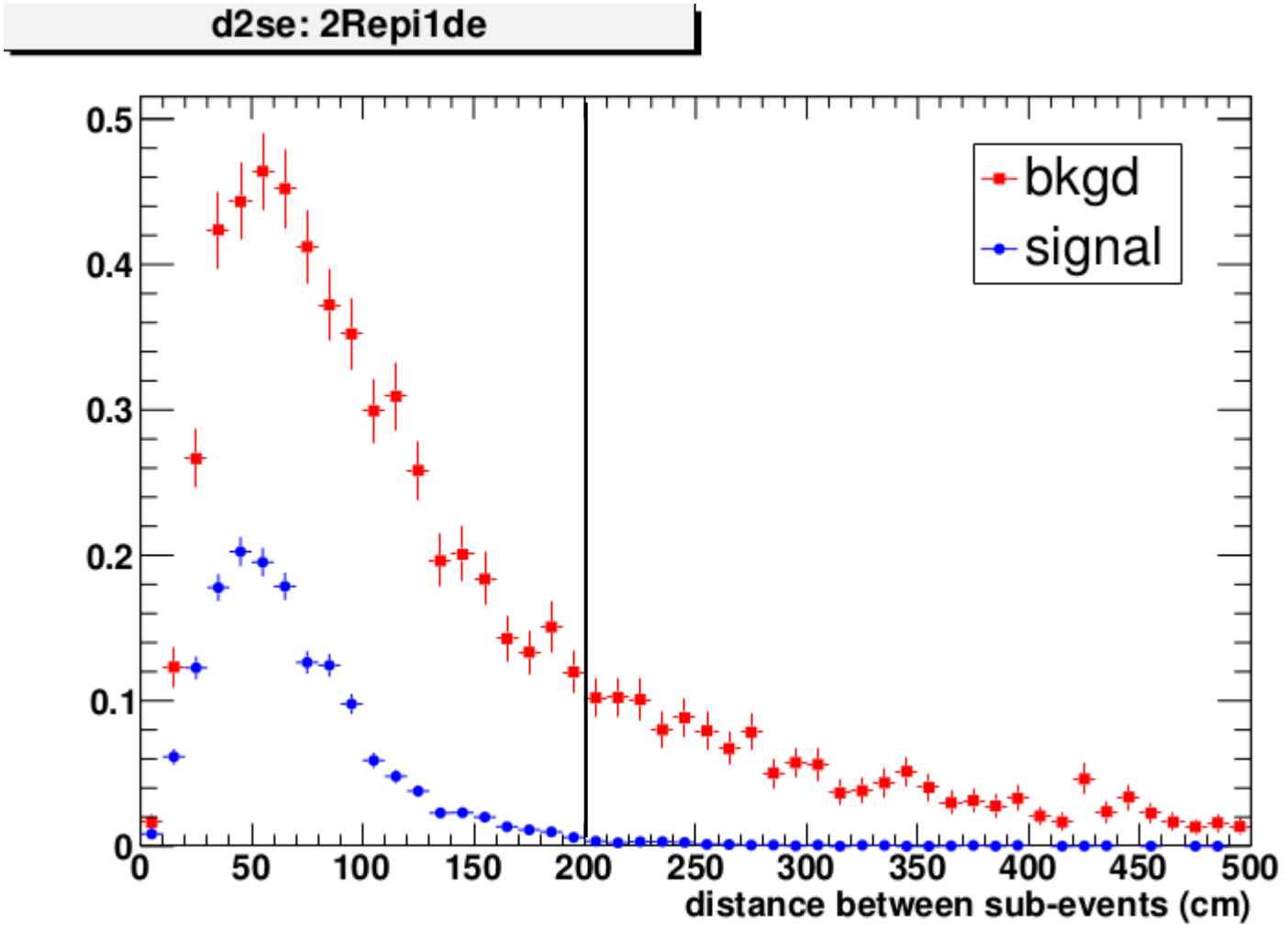

Wall vs p_e: 2Repi1de bkgd
Wall (cm)
p_e (MeV/c)

|p_e-p_pi| < 800MeV





d2se < 200 cm


d2se: 2Repi1de
bkgd
signal
0.5
0.4
0.3
0.2
0.1
0
0
50
100
150
200
250
300
350
400
450
500
distance between sub-events (cm)

Sample	cut	numu/numub CC	intrinsic nue/nueb CC	osc nue/nueb CC	numu/numub NC	intrinsic nue/nueb NC	Signal	Bkgd	Purity	FOM
2Repi	FCFV	414.82	27.42	42.45	168.32	4.77	42.45	615.33	0.06	1.66
	2 rings	66.04	5.10	4.99	83.02	2.11	4.99	156.26	0.03	0.39
	epi-like	6.74	2.28	2.34	5.19	0.19	2.34	14.40	0.14	0.57
	0 decay e	1.48	1.00	0.88	3.17	0.11	0.88	5.76	0.13	0.34
	p_e>100MeV	1.43	0.99	0.81	2.50	0.08	0.81	4.99	0.14	0.34
	|p_e-p_pi| <800MeV	**0.70**	**0.54**	**0.75**	**2.03**	**0.06**	**0.75**	**3.34**	**0.18**	**0.37**
2Repi1de	FCFV	414.82	27.42	42.45	168.32	4.77	42.45	615.33	0.06	1.66
	2 rings	66.04	5.10	4.99	83.02	2.11	4.99	156.26	0.03	0.39
	epi-like	6.74	2.28	2.34	5.19	0.19	2.34	14.40	0.14	0.57
	1 decay e	3.35	1.14	1.43	1.63	0.06	1.43	6.18	0.19	0.52
	p_e>100MeV	3.24	1.12	1.33	0.93	0.04	1.33	5.33	0.20	0.51
	|p_e-p_pi| <800MeV	1.85	0.68	1.28	0.66	0.03	1.28	3.22	0.28	0.60
	d2se<200cm	**1.06**	**0.65**	**1.26**	**0.60**	**0.03**	**1.26**	**2.33**	**0.35**	**0.66**

signal = oscillated nue/nueb CC

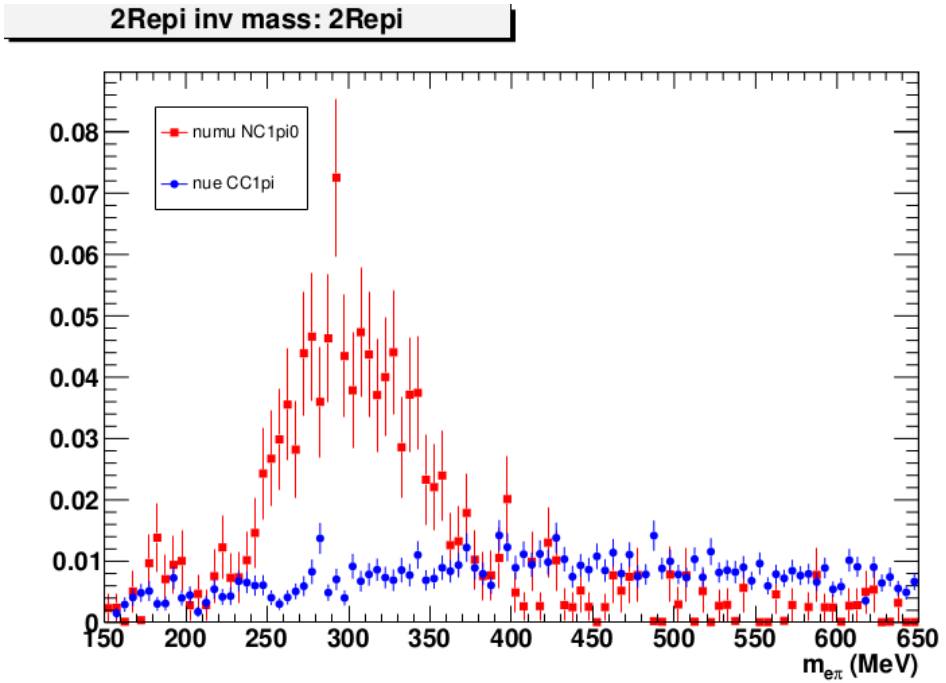
Sample	cut	nue NC 1pi+	nue NC 1pi-	nue NC 1pi0	nue NC Npi	nue NC 0pi	numu NC 1pi+	numu NC 1pi-	numu NC 1pi0	numu NC Npi	numu NC 0pi
2Repi	FCFV	0.61	0.49	1.34	0.83	1.51	18.96	14.91	50.38	26.47	57.60
	2 rings	0.17	0.14	0.83	0.15	0.81	5.02	3.79	34.72	4.25	35.23
	epi-like	0.04	0.03	0.03	0.03	0.05	0.96	0.74	1.22	1.04	1.23
	0 decay e	0.02	0.02	0.03	0.01	0.03	0.37	0.48	1.08	0.44	0.80
	p_e>100MeV	0.01	0.01	0.03	0.01	0.01	0.22	0.29	1.08	0.42	0.48
	|p_e-p_pi|<800MeV	**0.01**	**0.01**	**0.03**	**0.01**	**0.01**	**0.16**	**0.23**	**0.97**	**0.23**	**0.44**
2Repi1de	FCFV	0.61	0.49	1.34	0.83	1.51	18.96	14.91	50.38	26.47	57.60
	2 rings	0.17	0.14	0.83	0.15	0.81	5.02	3.79	34.72	4.25	35.23
	epi-like	0.04	0.03	0.03	0.03	0.05	0.96	0.74	1.22	1.04	1.23
	1 decay e	0.02	0.01	0.00	0.02	0.02	0.50	0.19	0.13	0.44	0.37
	p_e>100MeV	0.01	0.00	0.00	0.01	0.01	0.18	0.12	0.13	0.36	0.14
	|p_e-p_pi|<800MeV	0.01	0.00	0.00	0.01	0.01	0.13	0.08	0.09	0.24	0.12
	d2se<200cm	**0.01**	**0.00**	**0.00**	**0.01**	**0.01**	**0.12**	**0.07**	**0.08**	**0.22**	**0.11**

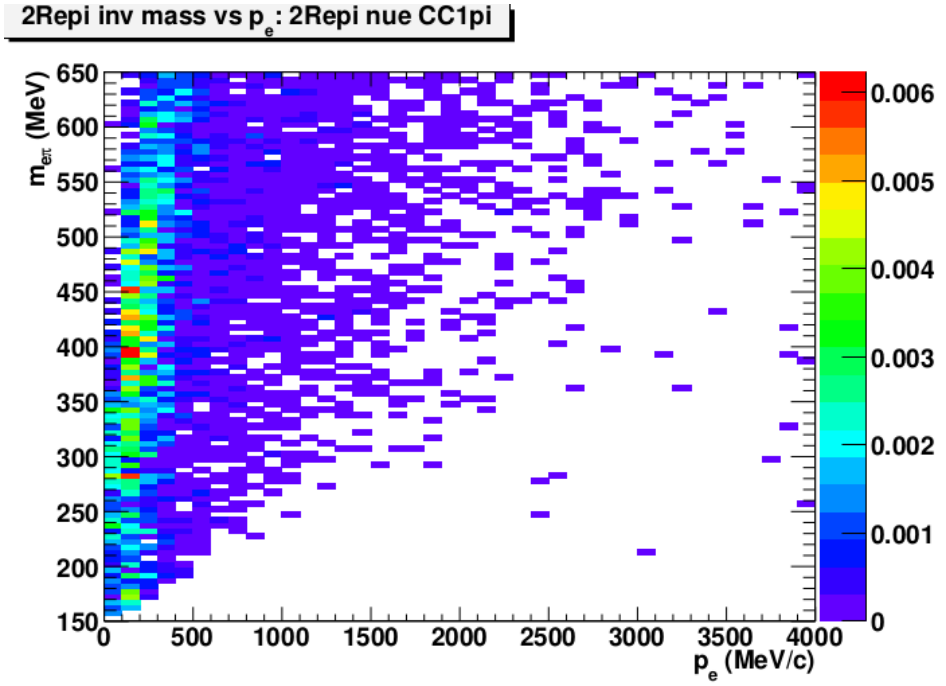
Sample	cut	nue CC1pi	nue CCQE	nue CCother	numu CC1pi	numu CCQE	numu CCother	Signal	Background	Purity	FOM
2Repi	FCFV	19.07	32.69	18.11	93.86	126.25	194.71	19.07	638.71	0.03	0.74
	2 rings	5.03	2.19	2.88	29.36	10.50	26.18	5.03	156.23	0.03	0.40
	epi-like	3.33	0.56	0.74	0.94	0.14	5.66	3.33	13.41	0.20	0.81
	0 decay e	1.09	0.49	0.30	0.11	0.07	1.29	1.09	5.55	0.16	0.42
	p_e>100MeV	1.02	0.49	0.29	0.10	0.04	1.29	1.02	4.78	0.18	0.42
	|p_e-p_pi|<800MeV	**0.75**	**0.37**	**0.18**	**0.09**	**0.04**	**0.56**	**0.75**	**3.34**	**0.18**	**0.37**
2Repi1de	FCFV	19.07	32.69	18.11	93.86	126.25	194.71	19.07	638.71	0.03	0.74
	2 rings	5.03	2.19	2.88	29.36	10.50	26.18	5.03	156.23	0.03	0.40
	epi-like	3.33	0.56	0.74	0.94	0.14	5.66	3.33	13.41	0.20	0.81
	1 decay e	2.19	0.06	0.31	0.49	0.05	2.81	2.19	5.42	0.29	0.79
	p_e>100MeV	2.08	0.06	0.31	0.41	0.05	2.79	2.08	4.57	0.31	0.81
	|p_e-p_pi|<800MeV	1.74	0.04	0.18	0.37	0.04	1.44	1.74	2.76	0.39	0.82
	d2se<200cm	**1.70**	**0.03**	**0.17**	**0.27**	**0.03**	**0.77**	**1.70**	**1.89**	**0.47**	**0.90**

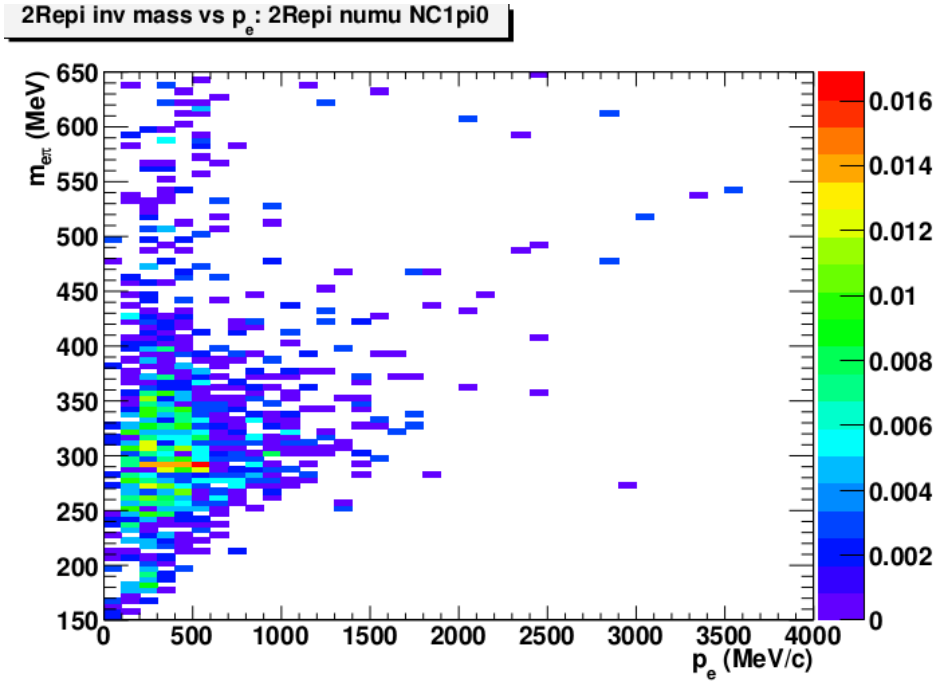
signal = nue CC1pi

Thoughts

- p_e > 100 MeV cut effective?
- Still some concerns about FOM in context of “wall”
- In 2Repi sample, p_e-p_pi cut good for “oscillated nue CC purity”, but not for “nue CC1pi purity”
- |p_e-p_pi| < 800 MeV likely too harsh of a cut
  - optimization will come later
- What is a better definition of “signal”?
  - oscillated nue CC or nue CC1pi? Perhaps oscillated nue CC1pi?
- 2Repi sample more of a concern
  - Main backgrounds: NC 1pi0 and numu CCnQE
- Potential improvements to 2Repi sample using inv. mass
  - See next slide


2Repi inv mass: 2Repi
numu NC1pi0
nue CC1pi
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
150
200
250
300
350
400
450
500
550
600
650
$m_{e\pi}$ (MeV)


2Repi inv mass vs p_e : 2Repi nue CC1pi
$m_{e\pi}$ (MeV)
650
600
550
500
450
400
350
300
250
200
150
0
500
1000
1500
2000
2500
3000
3500
4000
p_e (MeV/c)
0.006
0.005
0.004
0.003
0.002
0.001
0


2Repi inv mass vs p_e : 2Repi numu NC1pi0
$m_{e\pi}$ (MeV)
650
600
550
500
450
400
350
300
250
200
150
0
500
1000
1500
2000
2500
3000
3500
4000
p_e (MeV/c)
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0