2-ring ν_e CC1π^+ Selection Studies

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T2K-SK Pre-Meeting

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Overview

- Since last collaboration meeting:
  - focused on improving efficiency of 2Reπ(1de) selections
    - expanded selection beyond fqmrnring[0]==2 and fqmrpid[0][*]=1e1π $^{+/-}$
    - further explored use of BDTs

$\nu_e + p/n \rightarrow e^-$	1Re, 0 decay e	**(1Re)**
$\rightarrow e^- + \pi^+\ below\ CT$ $\rightarrow \mu \rightarrow e$	1Re, 1 decay e	**(1Re1de)**
$\rightarrow e^- + \pi^+\ above\ CT$	2Reπ, 0 decay e	**(2Reπ)**
$\rightarrow e^- + \pi^+\ above\ CT$ $\rightarrow \mu \rightarrow e$	2Reπ, 1 decay e	**(2Reπ1de)**

CT = Cherenkov Threshold

Original Baseline Cuts

	2Reπ	2Reπ1de
FCFV	evclass==1 && evis>30 && nhitac<16 && fqwall_2R>50	
2 rings	fqmrnring[0]==2	
eπ-like	(fqmrpid[0][0]==11 && fqmrpid[0][1]==211) || (fqmrpid[0][0]==211 && fqmrpid[0][1]==11)	
0 decay e	fqnse==1	fqnse==2
E_{rec} < 1.5GeV	nuErec_2repi(p_e,p_π)<1.5	

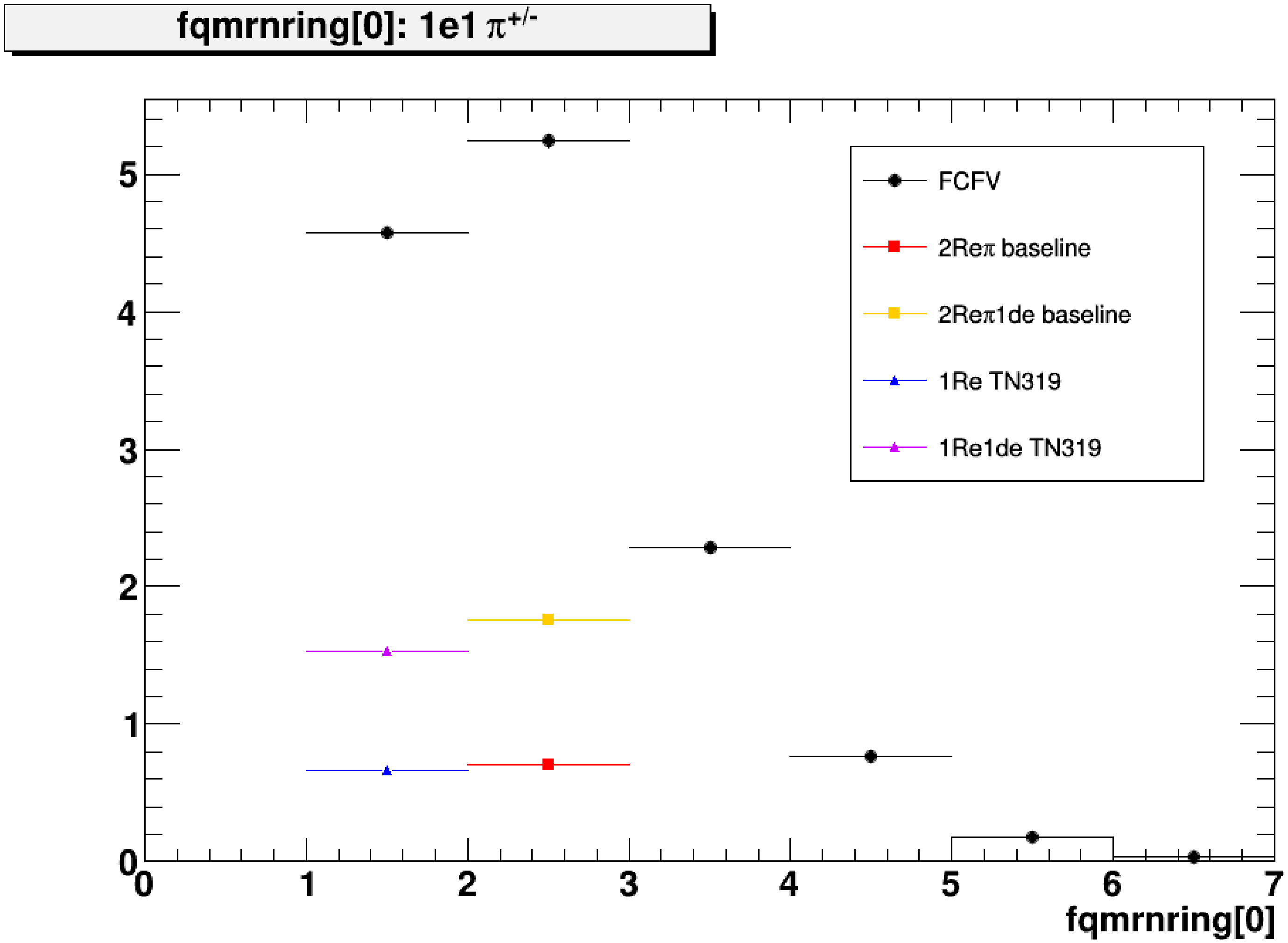
large efficiency loss at 2-ring cut

$$\mathrm{FOM} = \frac{S}{\sqrt{S+B}}$$

(neutrino beam mode, normal mass hierarchy, δ_{CP}=0, 10^{21} POT)

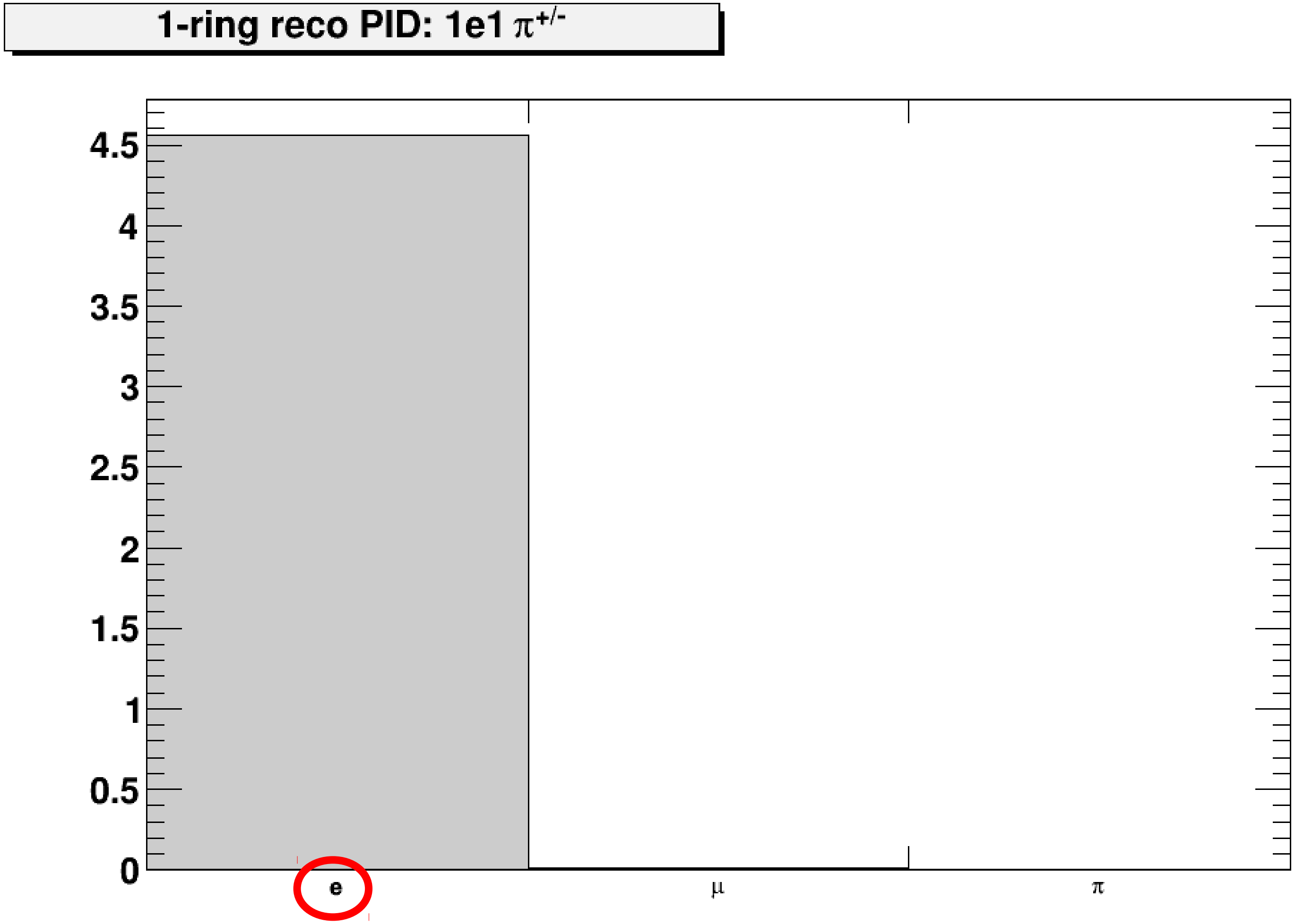
	2Reπ					2Reπ1de				
cut	true $1e1\pi^{+/-}$	other	purity	efficiency	FOM	true $1e1\pi^{+/-}$	other	purity	efficiency	FOM
FCFV	13.08	693.36	1.9%			13.08	693.36	1.9%		
2 rings	5.24	169.12	3.0%			5.24	169.12	3.0%		
eπ-like	3.87	14.57	21.0%			3.87	14.57	21.0%		
0 decay e	1.27	6.27	16.9%			2.47	5.76	30.1%		
E_{rec}<1.5GeV	0.71	3.10	**18.5%**	**27.5%**	**0.362**	1.75	2.15	**45.0%**	**34.9%**	**0.888**

- "true $1e1\pi^{+/-}$" events with one electron and one charged pion (above Cherenkov threshold + 30 MeV/c momentum), counted using the VCWORK stack where the pion must be flagged "to chase"
- Efficiency calculated relative to number of visible events in FCFV, with E_{rec}<1.5 GeV, separated into 1 sub-event and 2 sub-event samples



- Plot of fqmrnring[0] for true 1e1$\pi^{+/-}$ events
  - FCFV events, as well as events passing specific selections, are shown
- Lots of 1e1$\pi^{+/-}$ events are being reconstructed as 1-ring, 3-ring, and 4-ring events

What are true 1e1$\pi^{+/-}$ events being reconstructed as?



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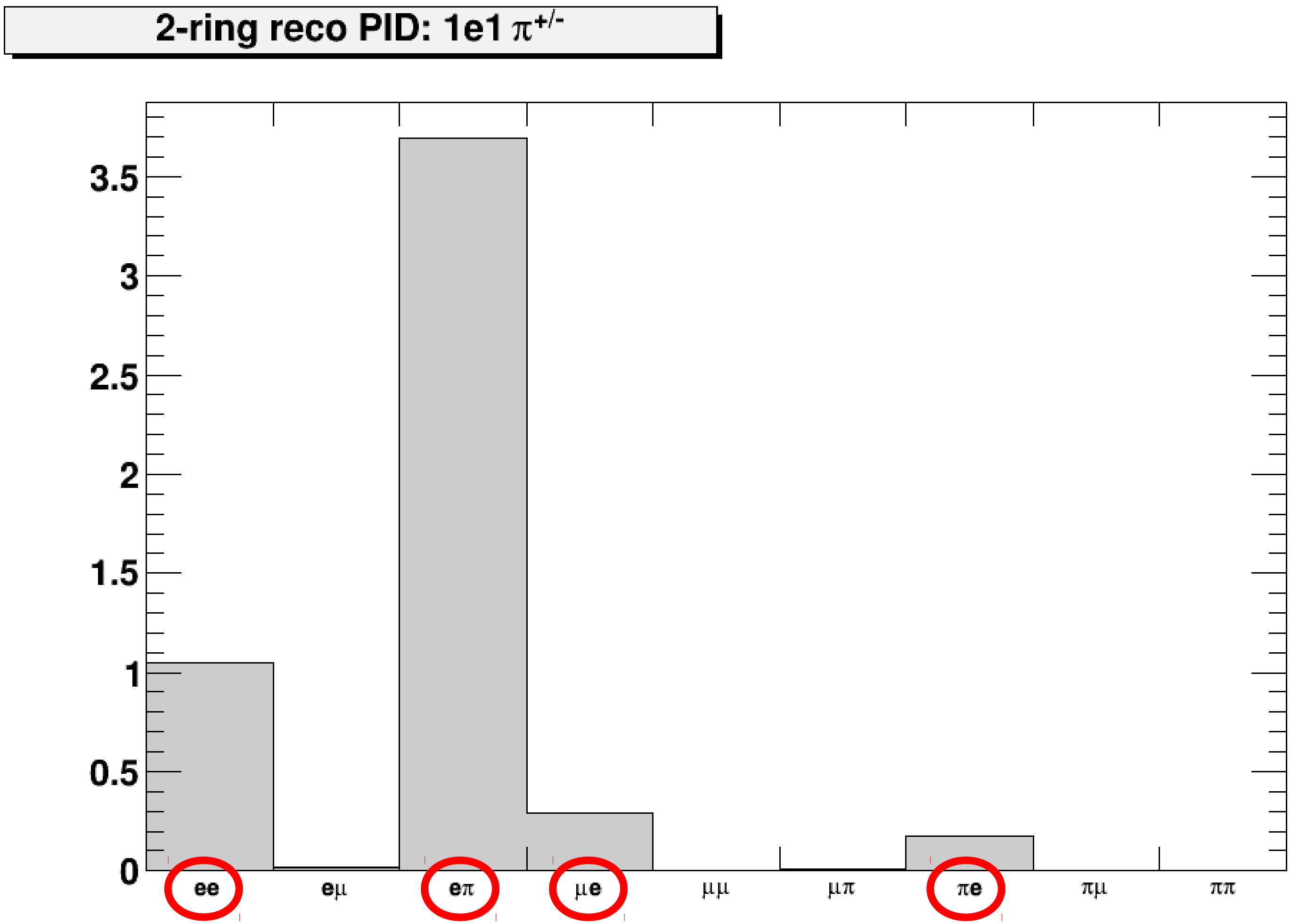

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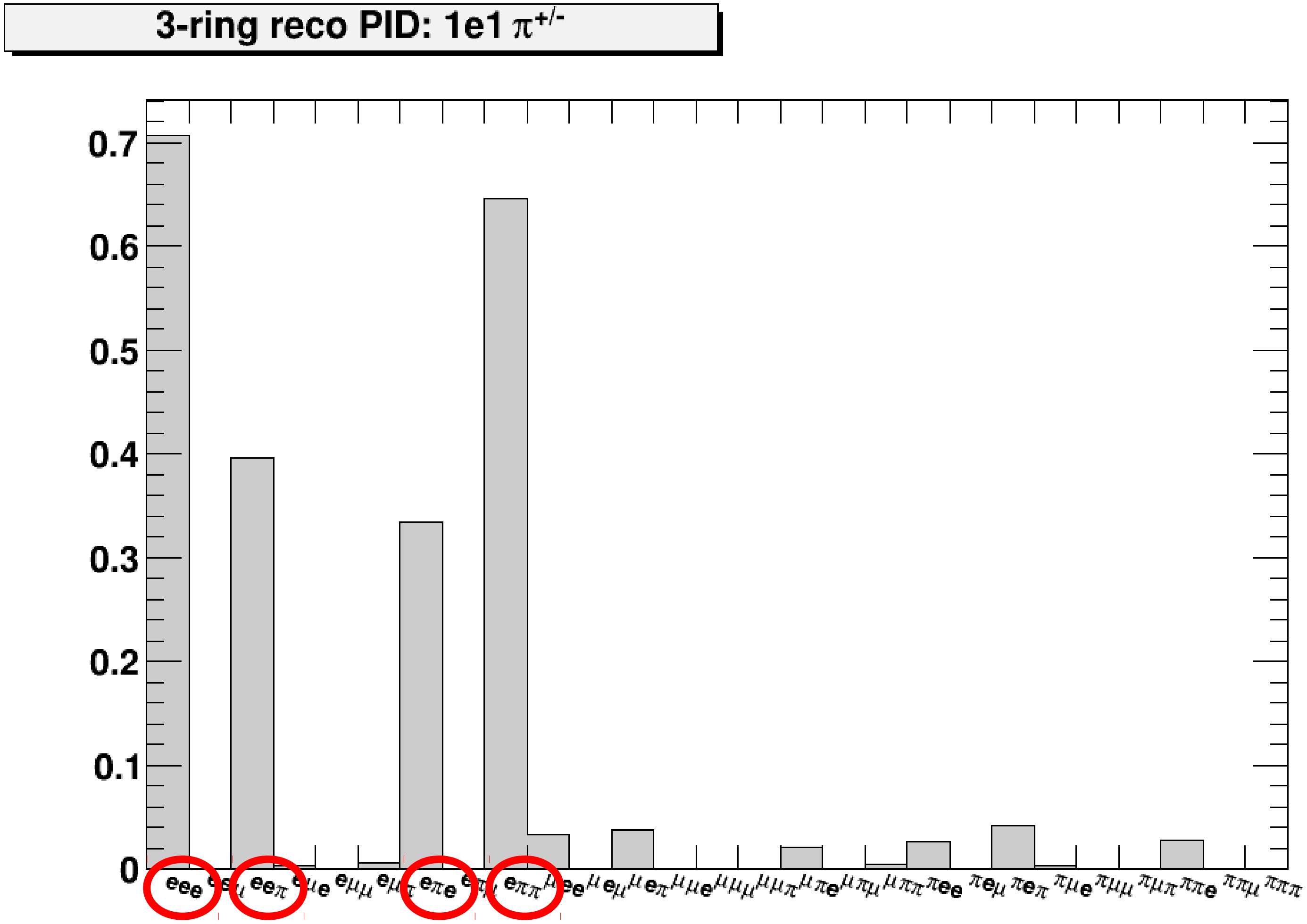

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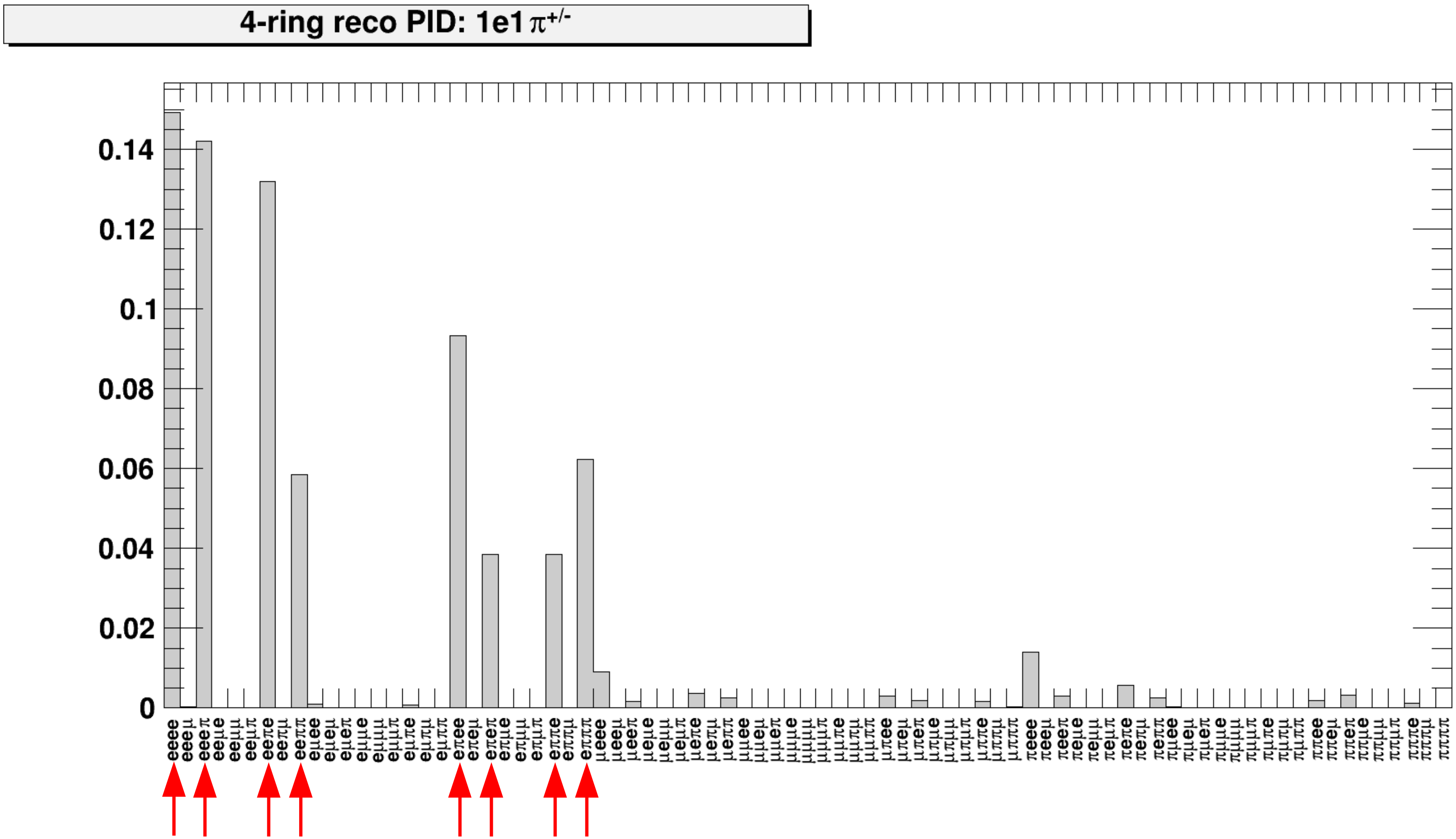

Improved eπ-like Cut

Added more "sub-samples" (fqmrpid[0][*] = 1Re, 2Ree, 2Rμe, 3Reππ) to 2-ring eπ-like cut

old baseline

	true 1e1π+/-	other	purity	efficiency	FOM	net purity	net eff.
0de	0.71	3.10	18.5%	27.5%	0.362	31.9%	32.4%
1de	1.75	2.15	45.0%	34.9%	0.888		

new baseline: 1Re + 2Reπ + 2Rπe + 2Ree + 2Rμe + 3Reππ

	true 1e1π+/-	other	purity	efficiency	FOM	net purity	net eff.
0de	0.70	2.32	23.3%	27.4%	0.405	32.6%	44.9%
1de	2.71	4.73	36.4%	53.8%	0.992		

red = 1de only

net purity: 31.9% → 32.6%
net efficiency: 32.4% → 44.9%

"new baseline" cuts applied to each sub-sample:

```
b_1re = ( fqnse==2 && ( nll1re-nll1rmu < -200. || fq1rmom[0][1] > 80. ) && fq1rmom[0][1] > 40. && ( nll1re-nll2rpie
< -50. || fq1rmom[0][1] > 80. ) )

b_2repi = ( ( fqnse==2 ) || ( fqnse==1 && nll2repi-nll2rpie < -100. ) )
b_2rpie = ( ( fqnse==1 && fqmrmom[0][1] > 40. && fqmrmom[0][0] > 340. ) || ( fqnse==2 && fqmrmom[0][1] > 40. ) )
b_2ree  = ( fqnse==2 && ( nll2ree-nll1rmu > -1000. && fqpi0mass[0] < 140. ) && ( nll2ree-nll2repi > -150. ) )
b_2rmue = ( fqnse==2 && ( fqmrmom[0][0] < 200. || nll2rmue-nll1rmu < -500. ) && ( nll2rmue-nll2repi > -100. ) )

b_3repipi = ( nll3repipi-nll2repi > -800.+fqmrmom[0][0]*1.60 )
```

Using BDTs

- Rather than adding sub-samples and cutting on each one by eye, use BDT
  - I’ve experimented with BDTs previously, but BDT input at the time was just the old baseline events (with poor efficiency)
- Two separate BDTs: 0 decay e, 1 decay e
- Start with sub-samples on previous slide as input to BDT
  - try to add more sub-samples, or otherwise generally expand efficiency of input
- Goal is to improve efficiency of BDT input such that the FOM can be improved

BDT Trials

- Preliminary cuts:
  - FCFV
  - possible 2Repi
    - v1:
      - 0 de: i2repi==0 || i2rpie==0 || i3repipi==0
      - 1 de: (i1re==0 && !Is1re && !Is1re1de) || i2ree==0 || i2repi==0 || i2rpie==0 || i2rmue==0 || i3repipi==0
    - v2:
      - 0 de: i2repi==0 || i2rpie==0 || i3repipi==0 || i4reeepi==0 || i4reepie==0 || i4reepipi==0 || i4repiee==0 || i4repipipi==0
      - 1 de: (i1re==0 && !Is1re && !Is1re1de) || i2ree==0 || i2repi==0 || i2rpie==0 || i2rmue==0 || i3repipi==0 || i4repipipi==0
    - v3:
      - 0 de: i2repi==0 || i2rpie==0 || i3reee==0 || i3reepi==0 || i3repie==0 || i3repipi==0
      - 1 de: (i1re==0 && !Is1re && !Is1re1de) || i2ree==0 || i2repi==0 || i2rpie==0 || i2rmue==0 || i3repipi==0
  - 1/2 sub-events
    - separate samples
  - $E_{rec}(1e,1\pi) < 1.5$ GeV
- v1 uses same sub-samples as the new baseline
- For each version, compared performance with different combinations of BDT variables

BDT Results (0 decay e)

	Trial	**v1** (input efficiency: **30.1%** 0de)					**v2** (input efficiency: **34.2%** 0de)					**v3** (input efficiency: **43.4%** 0de)				
		Signal	**Bkgd**	**Purity**	**Eff**	**FOM**	**Signal**	**Bkgd**	**Purity**	**Eff**	**FOM**	**Signal**	**Bkgd**	**Purity**	**Eff**	**FOM**
2Reπ	1	0.53	0.95	36.0%	20.8%	0.439	--	--	--	--	--	--	--	--	--	--
	2	0.55	0.70	44.1%	21.4%	0.493	--	--	--	--	--	--	--	--	--	--
	3	0.59	0.62	48.7%	22.9%	0.535	--	--	--	--	--	--	--	--	--	--
	4	0.55	0.51	52.1%	21.5%	0.537	--	--	--	--	--	--	--	--	--	--
	5	0.51	0.33	61.1%	20.0%	0.560	--	--	--	--	--	0.42	0.26	61.7%	16.5%	0.511
	6	--	--	--	--	--	0.56	0.49	53.1%	21.8%	0.545	0.43	0.28	61.1%	16.8%	0.513
	7	0.56	0.39	58.8%	21.8%	**0.574**	0.47	0.25	64.7%	18.2%	0.549	0.48	0.36	57.1%	18.5%	0.521
	8	0.56	0.41	58.0%	21.8%	0.570	0.54	0.38	58.6%	20.9%	0.561	0.49	0.34	59.5%	19.2%	0.541
	9	--	--	--	--	--	0.59	0.59	49.9%	22.9%	0.542	--	--	--	--	--

<u>Variables</u>

1) 1R v 1R nll, 1R v 2R nll, 2R v 2R nll
2) 1R v 1R nll, 1R v 2R nll, 2R v 2R nll, 1R+2R kinematics
3) 1R v 1R nll, 1R v 2R nll, 2R v 2R nll, 2R v 3R nll
4) 1R v 1R nll, 1R v 2R nll, 2R v 2R nll, 2R v 3R nll, 3R v 3R nll
5) 1R v 1R nll, 1R v 2R nll, 2R v 2R nll, 2R v 3R nll, 3R v 3R nll, 1R+2R kinematics
6) 1R v 1R nll, 1R v 2R nll, 2R v 2R nll, 2R v 3R nll, 3R v 3R nll, 1R+2R kinematics, 3R v 4R nll
7) 1R v 1R nll, 1R v 2R nll, 2R v 2R nll, 2R v 3R nll, 3R v 3R nll, 1R+2R kinematics, E_{rec}, towall e, towall π, p_{low}, $m_{\pi 0}$
8) 1R v 1R nll, 1R v 2R nll, 2R v 2R nll, 2R v 3R nll, 3R v 3R nll, 1R+2R kinematics, E_{rec}, towall e, towall π, p_{low}, $m_{\pi 0}$, fit indices of 1R, 2R, and 3R fits
9) 1R v 1R nll, 1R v 2R nll, 2R v 2R nll, 2R v 3R nll, 3R v 3R nll, 1R+2R kinematics, E_{rec}, towall e, towall π, p_{low}, $m_{\pi 0}$, fit indices of 1R, 2R, and 3R fits, 3R v 4R nll

- Note that missing 3-ring and 4-ring nlls are padded with 0
- v1 gives the best performance, despite having the lowest input efficiency
- Despite adding MR fit indices to v2 and v3 (trials 8 and 9), they are still unable to out-perform v1 without indices

BDT Results (1 decay e)

		v1 (input efficiency: **30.1%** 0de)					**v2** (input efficiency: **34.2%** 0de)				
	Trial	**Signal**	**Bkgd**	**Purity**	**Eff**	**FOM**	**Signal**	**Bkgd**	**Purity**	**Eff**	**FOM**
	1	2.31	2.46	48.4%	45.9%	1.056	--	--	--	--	--
	2	2.22	1.66	57.2%	44.2%	1.127	--	--	--	--	--
	3	2.54	2.69	48.5%	50.5%	1.110	--	--	--	--	--
	4	2.50	2.47	50.4%	49.8%	1.123	--	--	--	--	--
2Reπ	5	2.44	1.85	56.8%	48.5%	1.177	--	--	--	--	--
	6	--	--	--	--	--	2.23	1.56	58.9%	44.4%	1.146
	7	2.39	1.72	58.1%	47.6%	1.179	2.07	1.07	66.0%	41.3%	1.170
	8	2.32	1.43	61.8%	46.1%	**1.197**	2.33	1.67	58.3%	46.4%	1.166
	9	--	--	--	--	--	2.24	1.90	56.0%	48.2%	1.165

Variables
1) 1R v 1R nll, 1R v 2R nll, 2R v 2R nll
2) 1R v 1R nll, 1R v 2R nll, 2R v 2R nll, 1R+2R kinematics
3) 1R v 1R nll, 1R v 2R nll, 2R v 2R nll, 2R v 3R nll
4) 1R v 1R nll, 1R v 2R nll, 2R v 2R nll, 2R v 3R nll, 3R v 3R nll
5) 1R v 1R nll, 1R v 2R nll, 2R v 2R nll, 2R v 3R nll, 3R v 3R nll, 1R+2R kinematics
6) 1R v 1R nll, 1R v 2R nll, 2R v 2R nll, 2R v 3R nll, 3R v 3R nll, 1R+2R kinematics, 3R v 4R nll
7) 1R v 1R nll, 1R v 2R nll, 2R v 2R nll, 2R v 3R nll, 3R v 3R nll, 1R+2R kinematics, E_{rec}, towall e, towall π, p_{low}, $m_{\pi0}$, d2se
8) 1R v 1R nll, 1R v 2R nll, 2R v 2R nll, 2R v 3R nll, 3R v 3R nll, 1R+2R kinematics, E_{rec}, towall e, towall π, p_{low}, $m_{\pi0}$, d2se, fit indices of 1R, 2R, and 3R fits
9) 1R v 1R nll, 1R v 2R nll, 2R v 2R nll, 2R v 3R nll, 3R v 3R nll, 1R+2R kinematics, E_{rec}, towall e, towall π, p_{low}, $m_{\pi0}$, d2se, fit indices of 1R, 2R, and 3R fits, 3R v 4R nll

- Note that missing 3-ring and 4-ring nlls are padded with 0
- for 1 decay e sample, v3 is identical to v1 so it is not shown
- As with the 0 decay e sample, v1 gives the best performance

BDT Architecture

- Previous slides used BDT parameters of MaxDepth=3 and NTrees=850
- How dependent is BDT performance on these parameters?
  - There are a number of other BDT parameters that the user can specify in TMVA
- Grid search across MaxDepth and NTrees to examine FOM dependence

BDT Grid Search Results

Thoughts and Future Work

- Final attempt to increase efficiency of BDT input using loose cuts
  - different approach than adding sub-samples
- Dependence of BDT on random seed?
- Move towards focusing on systematic uncertainties

Backup

- baseline detailed cutflow (old and new)
- neut modes of “true $1e1\pi^{+/-}$” events
- Purity/efficiency plots for each sub-sample
- ROC curves for BDTs
- Reconstruction metrics (E_{res}, p_{res}, etc.)