Analysis Updates

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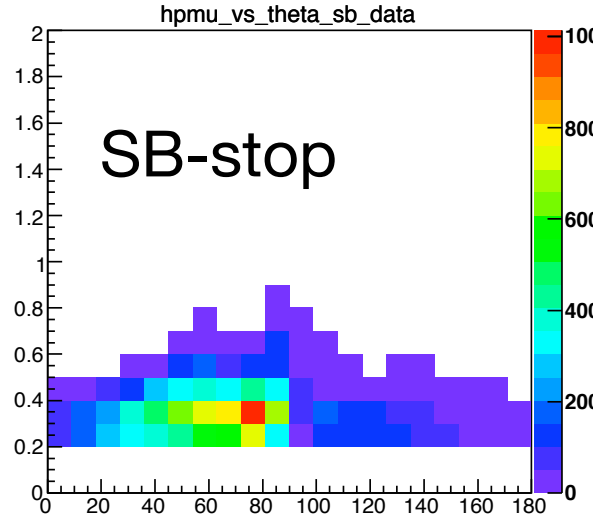
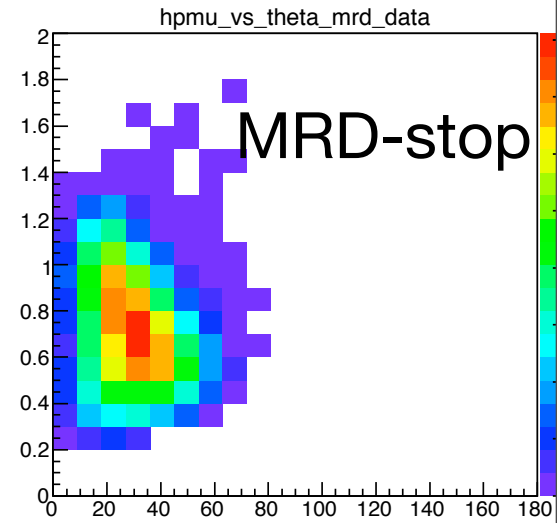
SciBooNE Collaboration Meeting

Contents

- Summary of the current status and issues of the SB spectrum fit
- Study of proton track contamination in CC-inclusive sample
- Spectrum fit with new proton error

Spectrum fit





Contents up to the page 8 of this slides are summarized in the technote, which uploaded to the indico page.

- Fit pmu vs. thetamu distributions to extract the scale factor as a function of true Enu.

μ (f_i(i=0,..,5), M_A^{QE}, κ)

$$\chi^2 = \sum_{i,j}^{Nbins} (n_i - \mu_i)(V_{sys} + V_{stat})^{-1}_{ij}(n_j - \mu_j)$$

- We have 159 pmu-thetamu bins --- V is a 159 x 159 matrix

	f_0	f_1	f_2	f_3	f_4	f_5
E_ν (GeV)	-0.5	0.5-0.75	0.75-1.0	1.0-1.25	1.25-1.75	1.75-

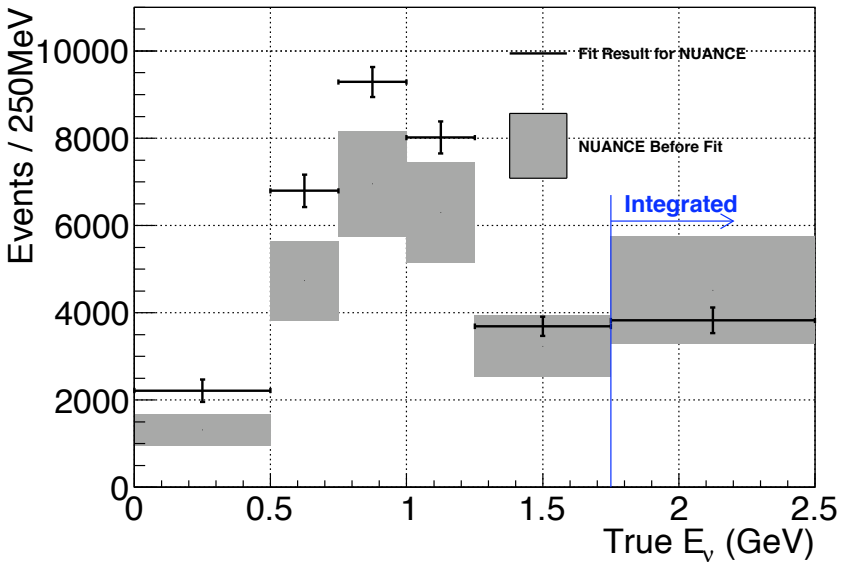
Current List of the Systematic Uncertainties

- Neutrino interaction:
  - Table on the right
  - CC1π low-Q2 shape
  - FSI: π charge exchange / absorption
- Detector response
  - SciBar/EC/MRD dE/dx: 3,10,3%
  - Pion interaction : 10%
  - Dirt density
  - Cross-talk / Birk's constant / 1pe resolution
- Neutrino Flux
  - (negligibly small for the spectrum fit)

Parameter	Nominal value	Variation
p_F	220 MeV/c	± 30
E_B	34 MeV/c	± 9
QE M_A	1.234 GeV	± 0.234
QE κ	1.022	± 0.022
Resonant π M_A	1.10 GeV	± 0.275
Coherent π M_A	1.03 GeV	± 0.275
Multi-π M_A	1.30 GeV	± 0.52
ΔS	0	± 0.1

Current Results of SciBooNE Spectrum Fit

- Obtain the scale factors by minimizing the chi2.
- However, there are several issues:
  - Large chi2 value: 210/153
  - Large scale factors at low-E
- Able to constrain further by fitting MA/kappa simultaneously

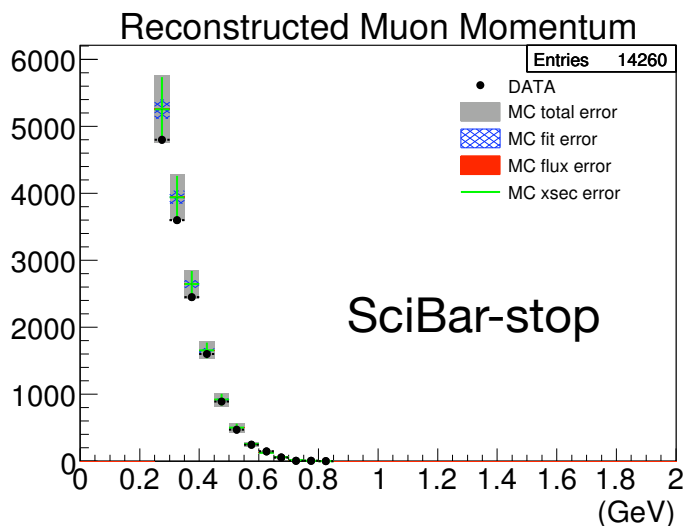


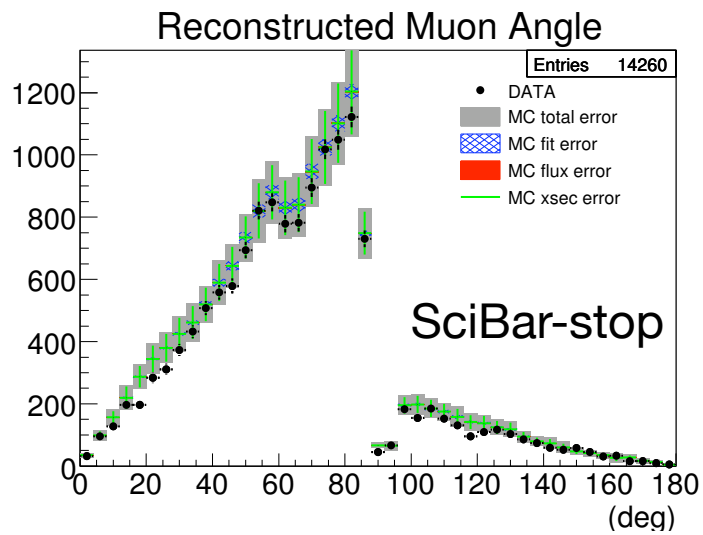
	f_0	f_1	f_2	f_3	f_4	f_5
Best fit	1.689	1.435	1.336	1.273	1.141	0.847
Error	0.196	0.078	0.049	0.058	0.069	0.064
f_0	1.0000	0.2457	-0.0903	-0.4029	-0.3806	-0.0252
f_1	0.2457	1.0000	-0.0942	-0.3697	-0.3834	-0.1301
f_2	-0.0903	-0.0942	1.0000	-0.0979	-0.0191	-0.2997
f_3	-0.4029	-0.3697	-0.0979	1.0000	-0.0155	0.1284
f_4	-0.3806	-0.3834	-0.0191	-0.0155	1.0000	-0.3234
f_5	-0.0252	-0.1301	-0.2997	0.1284	-0.3234	1.0000

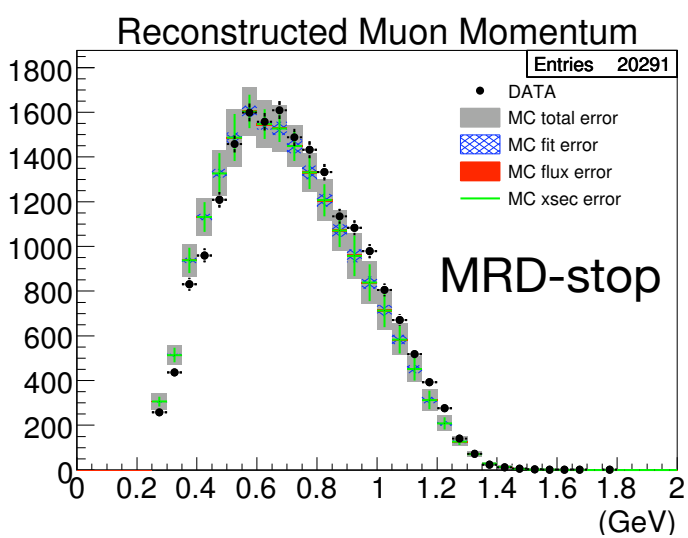
Issue 1: Bad χ^2

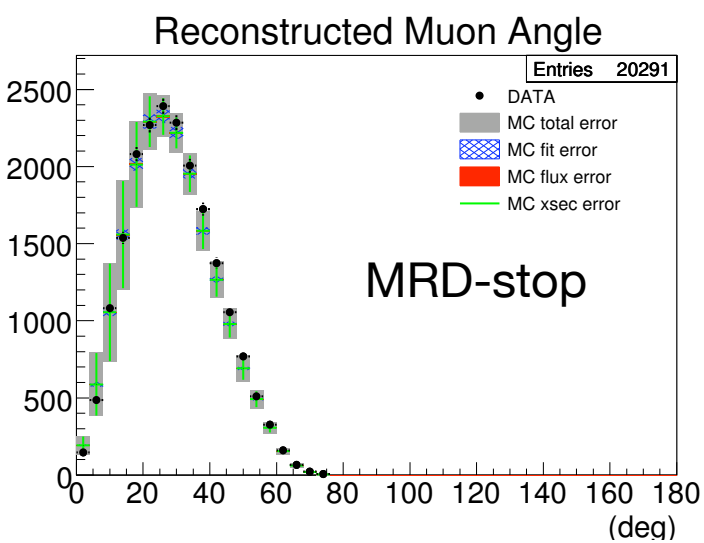
- The chi2 after fitting is 210/153 dof, whose probability is only 4×10^{-3}.
- This indicate there is missing systematic error need to be considered.
  - Need to fix before applying to MiniBooNE.
- Possible sources:
  - MC prediction of second tracks?
    - Proton and pion distributions?
  - Unknown detector effect?

Issue 2: Data/MC difference after fit









- Clear data/mc discrepancy in Pμ distribution.
- This appeared after implementing the systematic uncertainties.
- Due to incomplete systematic uncertainty???
- This also lead to miss-estimate MiniBooNE flux.

Issue 3: Possible Improvements?

- As shown in the previous page, the error is dominated by the cross-section uncertainties.
- The cross-section uncertainty is also a dominant error for MiniBooNE distribution after applying SciBooNE constraint.
  - Especially, errors of QE cross-section parameters are large
- The sensitivity should be improved if we can constraint MA/kappa as well.
  - Since there is strong correlation between the spectrum shape and MA/kappa, we need to fit the spectrum and MA/kappa simultaneously.

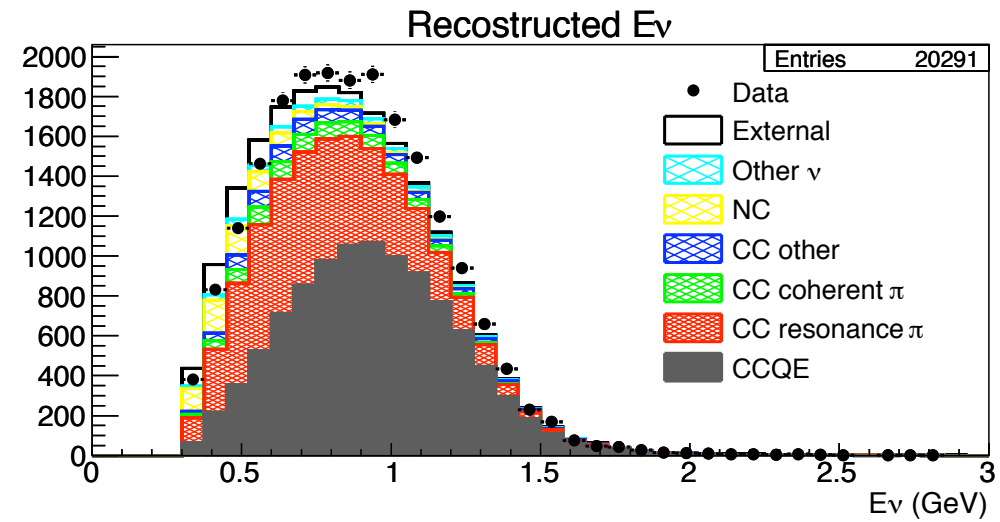
Approaches to these issues:

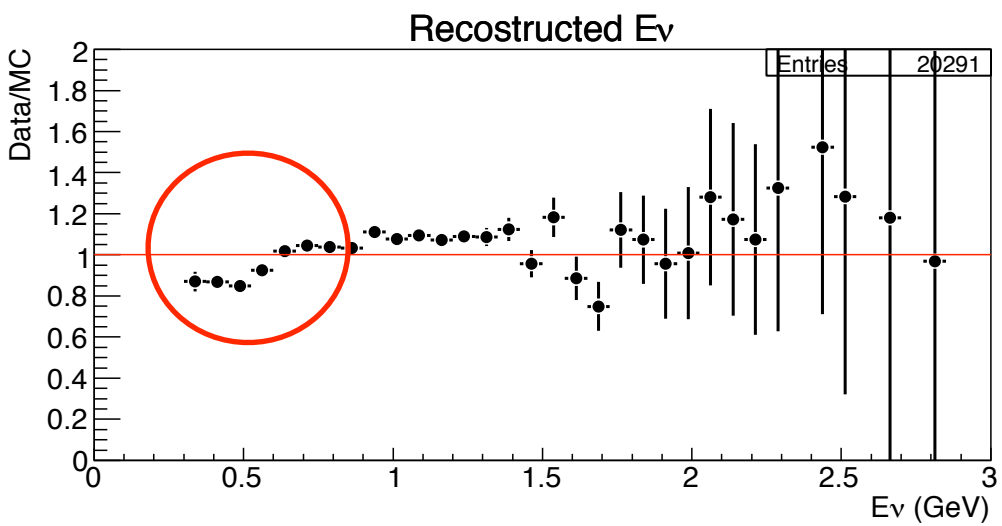
- Look for the source of data/MC discrepancy, and understand the cause of the bad chi2:
  - Doubt the proton track contamination

    A study of the proton miss-reconstruction will be described in this talk.
- Then, make MA/kappa fit.

Study of proton tracks in CC-inclusive sample

A data deficit at low-E MRD-stopped events:



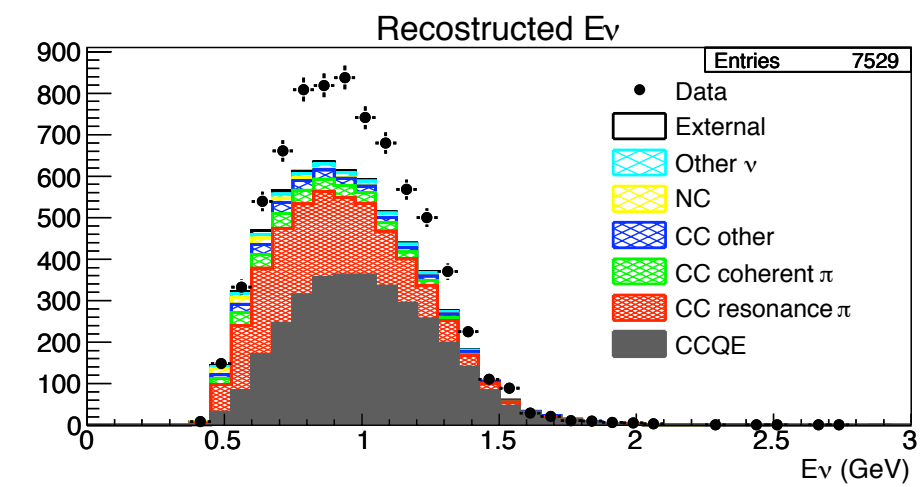


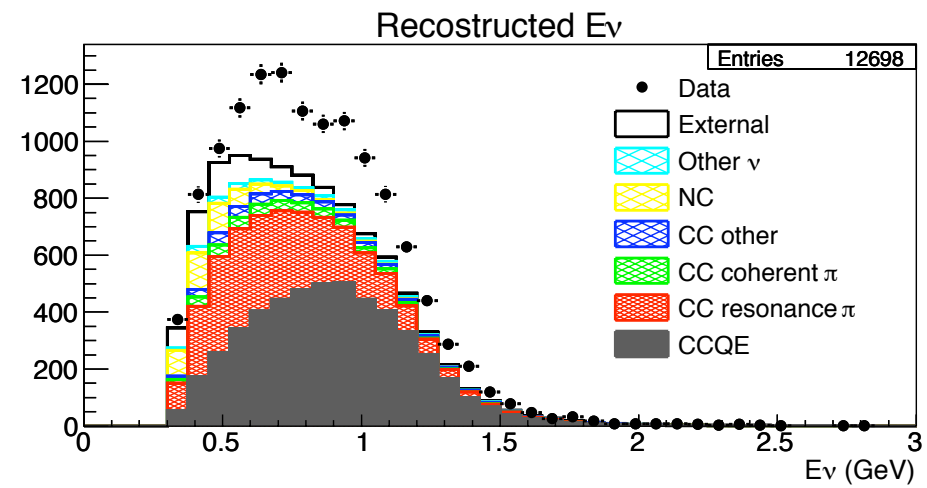
Before Fit, MRD-match normalized

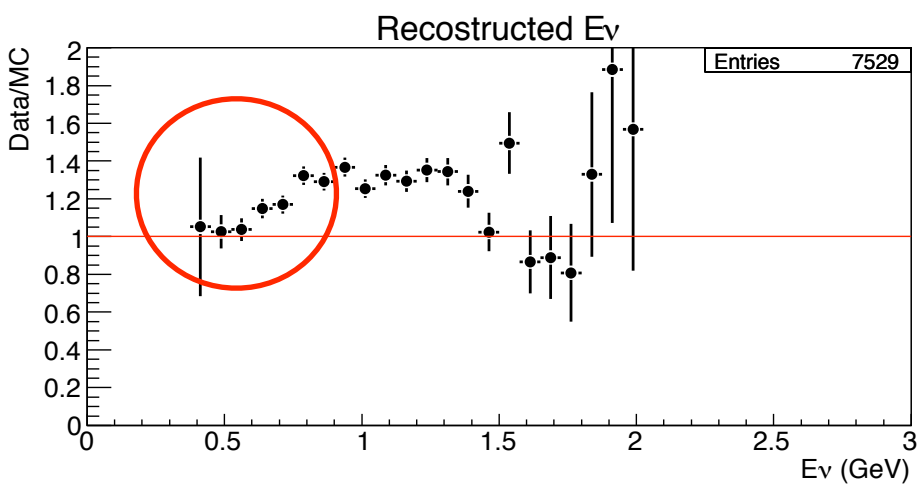
- We see data deficit at low-enu region
- In Kedall's oscillation fit, chi2 improved if we remove 3 low-enu bins.

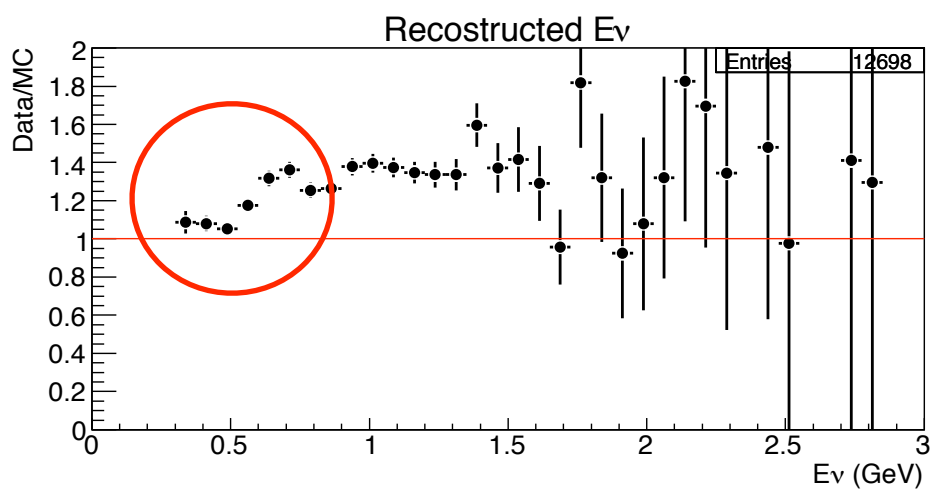
Z<83.84

Absolute normalization
Z>83.84





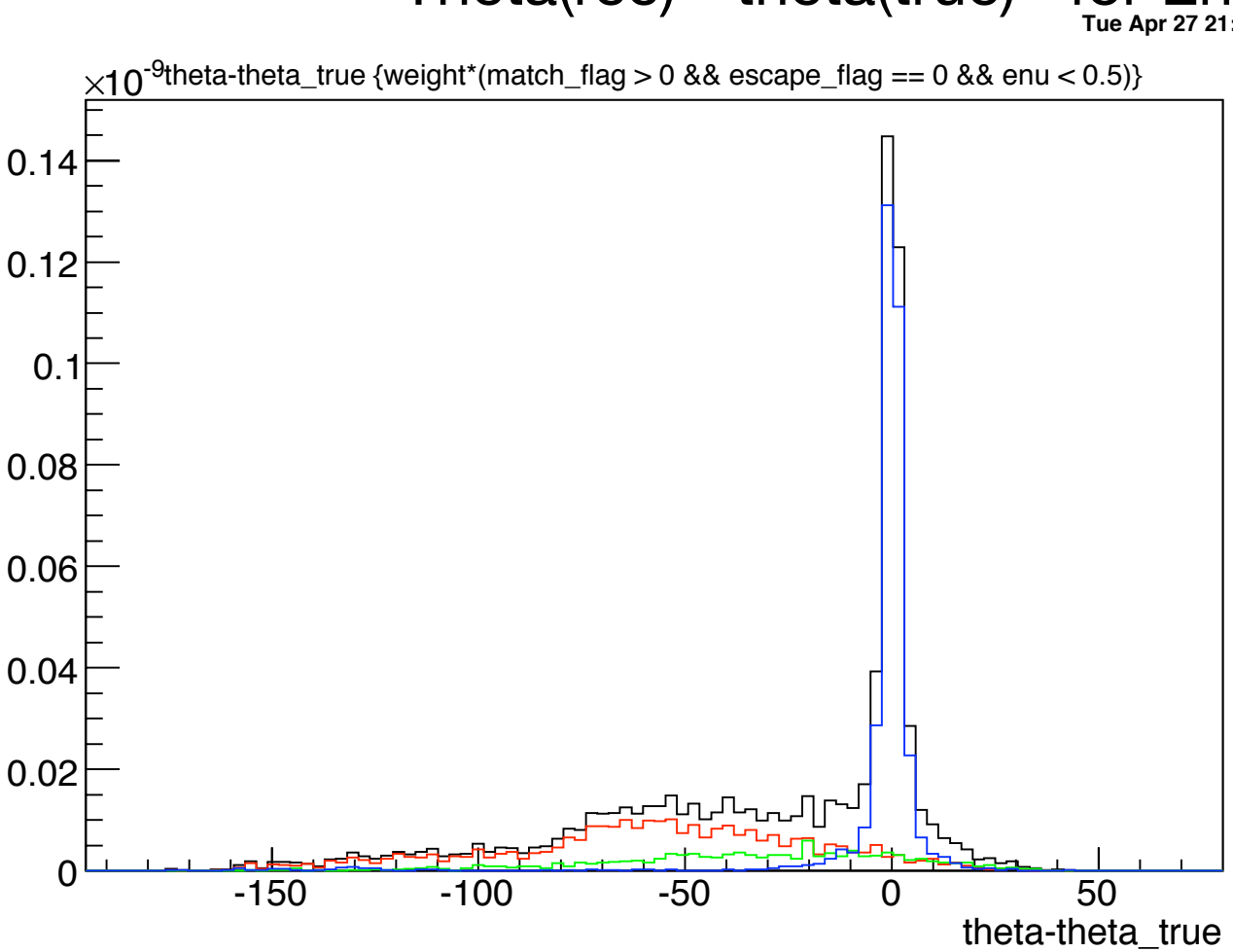




We see same trend at both low-enu and large-enu region
Doesn't look like EC/MRD events.

What kind of events at Low-enu region?

Theta(rec) - theta(true) for Enu(rec) < 0.5



(true) PID fo MRD-matched track:

blue : muon

red : proton

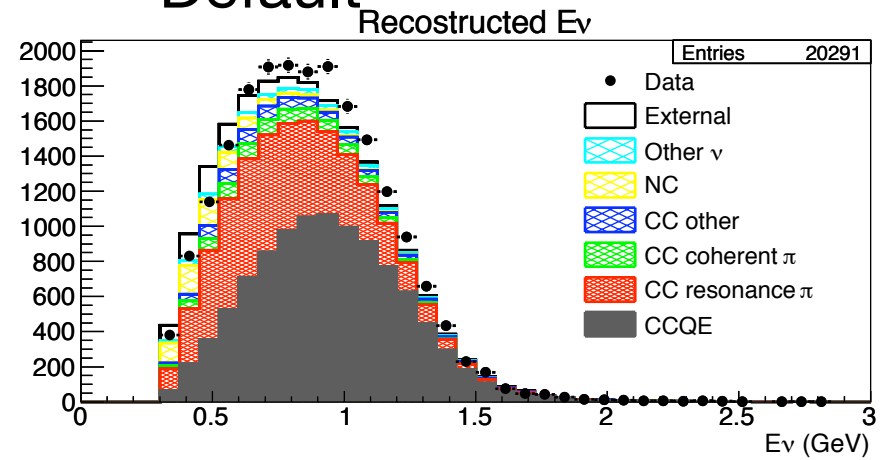
green : pion

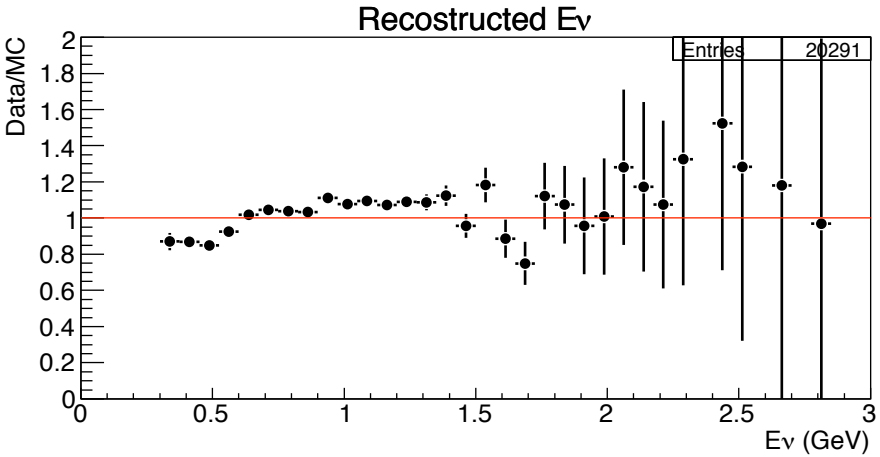
Large fraction of proton tracks miss-reconstructed

What happened if we remove proton?

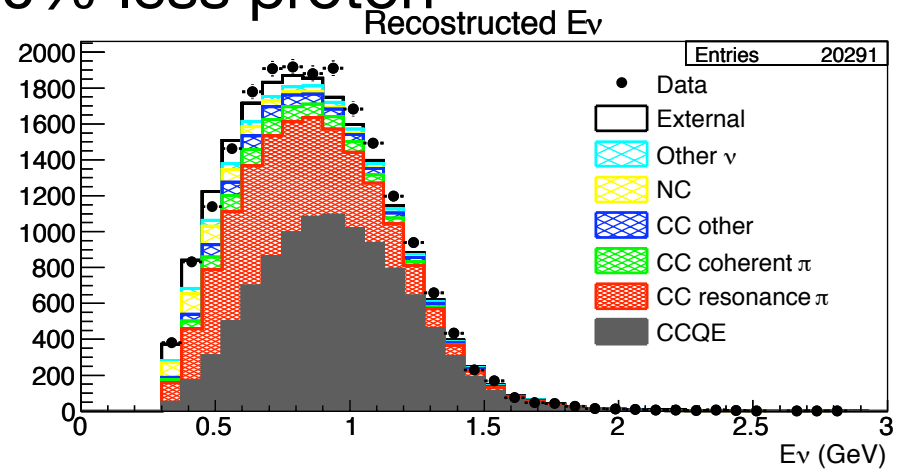
Randomly remove 50% of proton track from the MC

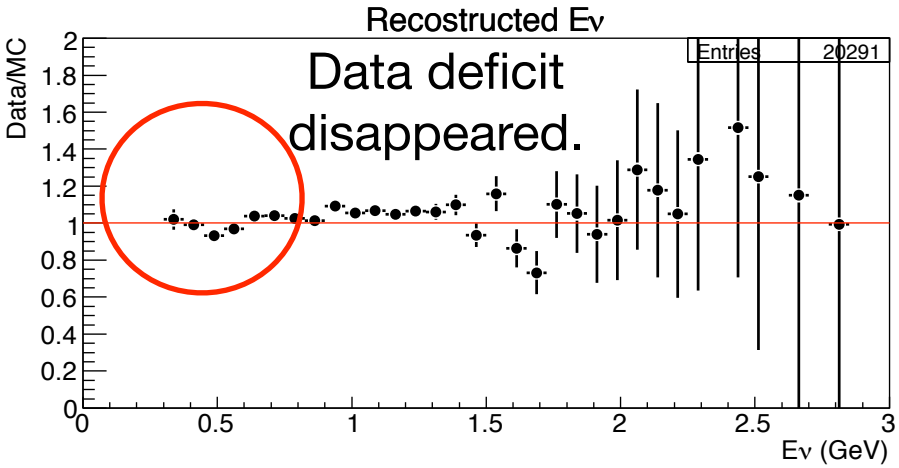
Default





50% less proton

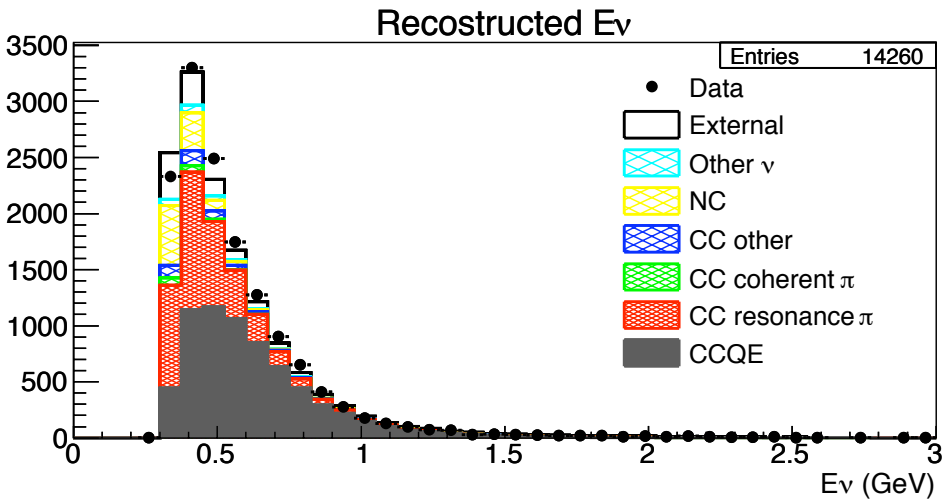


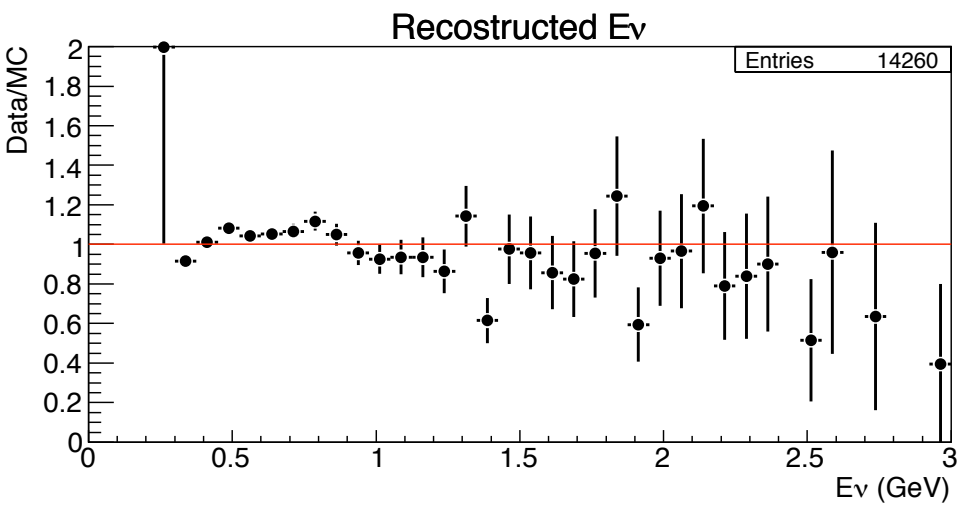


SciBar-stopped sample

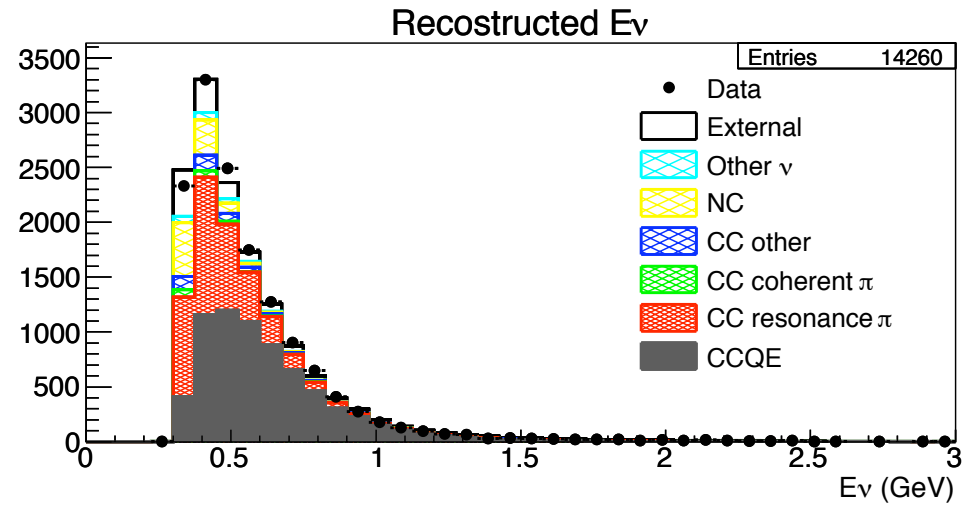
Normalized by MRD-matched sample

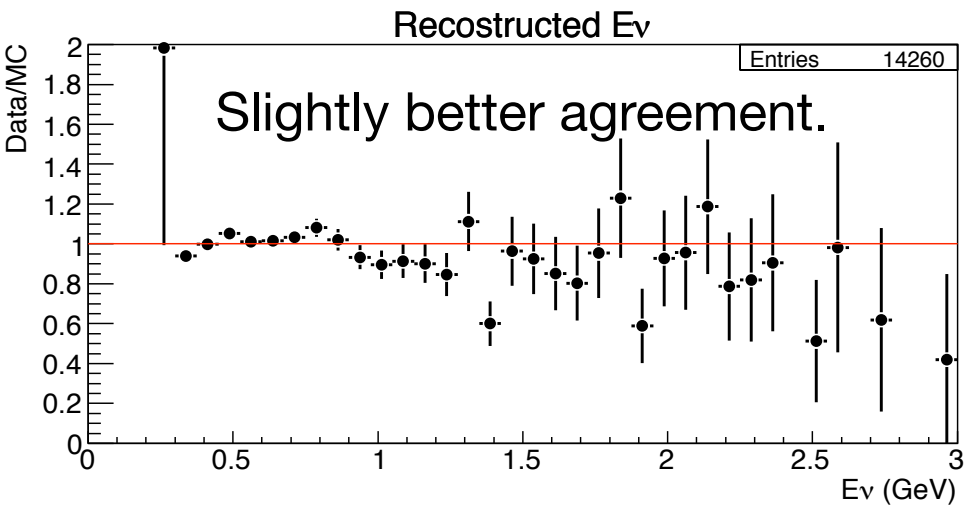
Default





50% less proton



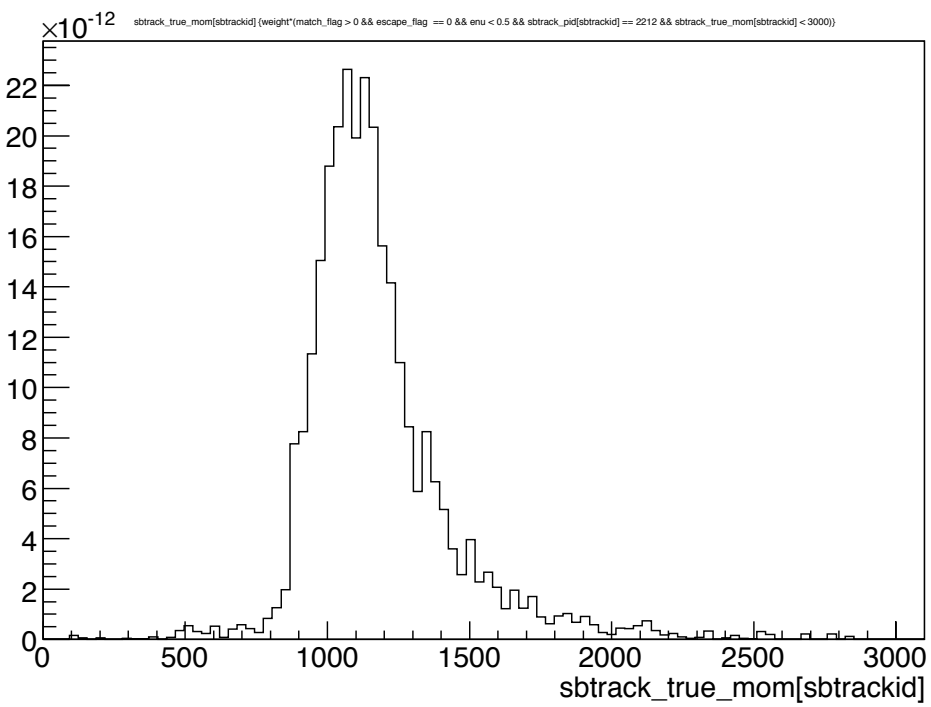


Low-EnuRec sample

Proton Selection:

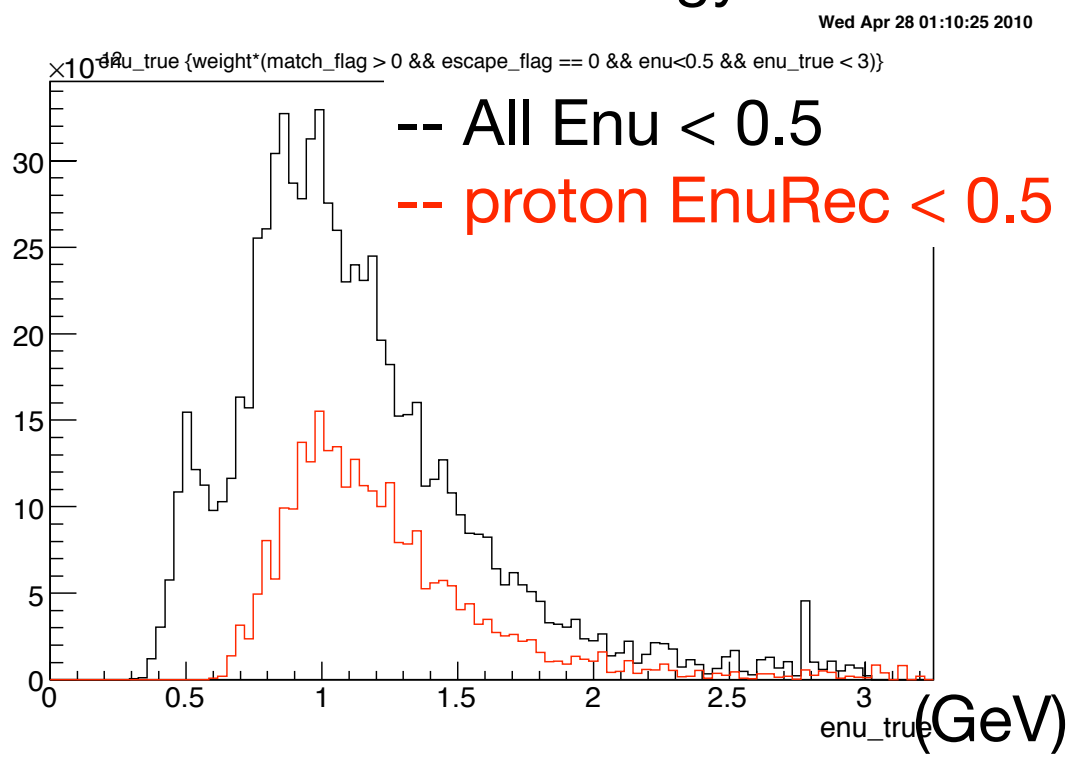
- EnuRec < 0.5 GeV
- MRD-stopped
- Miss-reconstruct proton tracks as muon (mrd-matched) tracks

True Proton Momentum



(MeV)

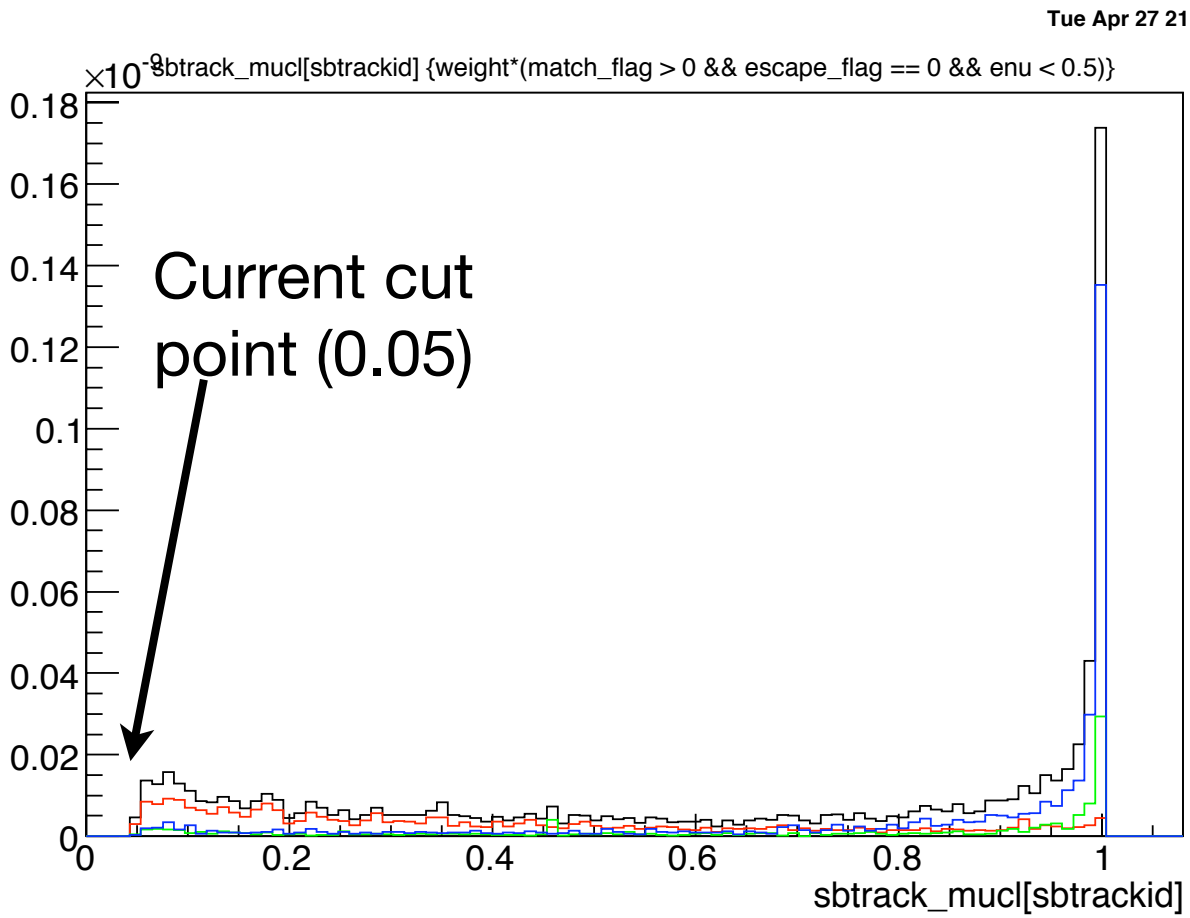
True Neutrino Energy



(GeV)

Actually, most of events are migration from high-energy events...

MuCL for the primary track



MRD-stopped
EnuRec < 0.5 GeV

-- all
-- muon
-- proton
-- pion

Requiring larger MuCL should be able to improve the situation.

Proton tracks reconstructed as "muon"

MRD-stopped sample

Fraction of proton tracks which miss-identified as muon

MuCL	> 0	> 0.05	> 0.1	> 0.3	> 0.5	> 0.7
NUANCE	9.4%	7.5	7.0	5.4	4.3	3.3
NEUT	6.8	5.4	5.0	3.9	3.1	2.3
NUANCE/ NEUT	1.39	1.39	1.39	1.40	1.41	1.41

Proton miss-id rate reduced as increasing MuCL requirement.

There is ~40% difference between NEUT and NUANCE, almost independent to the MuCL values.

Proton tracks reconstructed as "muon"

SciBar-stopped sample

Fraction of proton tracks which miss-identified as muon

MuCL	> 0	> 0.05	> 0.1	> 0.3	> 0.5	> 0.7
NUANCE	20.6	4.7	4.0	2.8	2.3	1.9
NEUT	16.2	3.4	2.9	2.0	1.6	1.3
NUANCE/ NEUT	1.28	1.38	1.38	1.39	1.42	1.42

~40% difference between NEUT and NUANCE once MuCL > 0.05 is required.

Approaches for Proton Miss-reconstruction

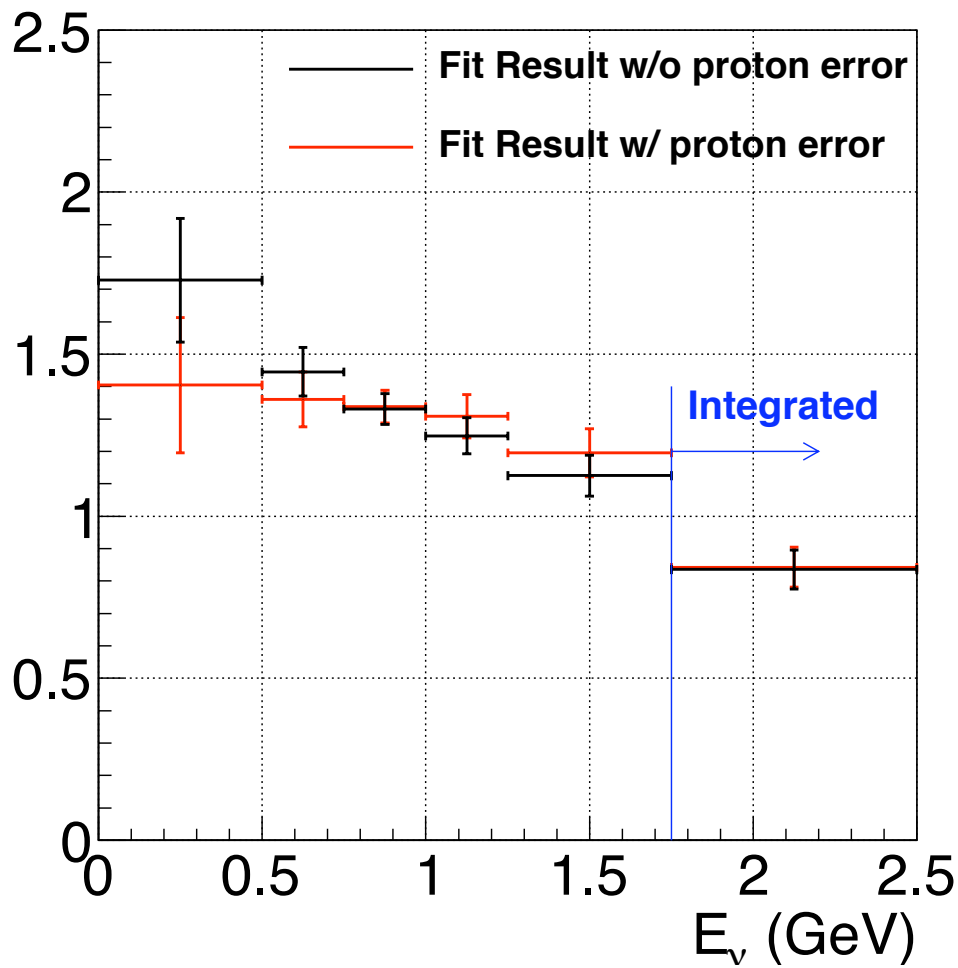
- Assign new systematic error:
  - Take NEUT/NUANCE difference (40%) and set as systematic uncertainty.
- Make tighter MuCL cut
  - Test larger MuCL cut point and see the distribution

Spectrum (and MA/kappa) Fit with new proton error

Effect of the new error for proton tracks

- Add 40% error for proton "reconstruction efficiency"
- The scale factor become "flatter"
  - Data/MC discrepancy reduced.
- chi2 = 210/153 --> 201/153
  - A little bit improved
  - Still not so good.

Fit results for NUANCE prediction with MuCL > 0.05 (default)



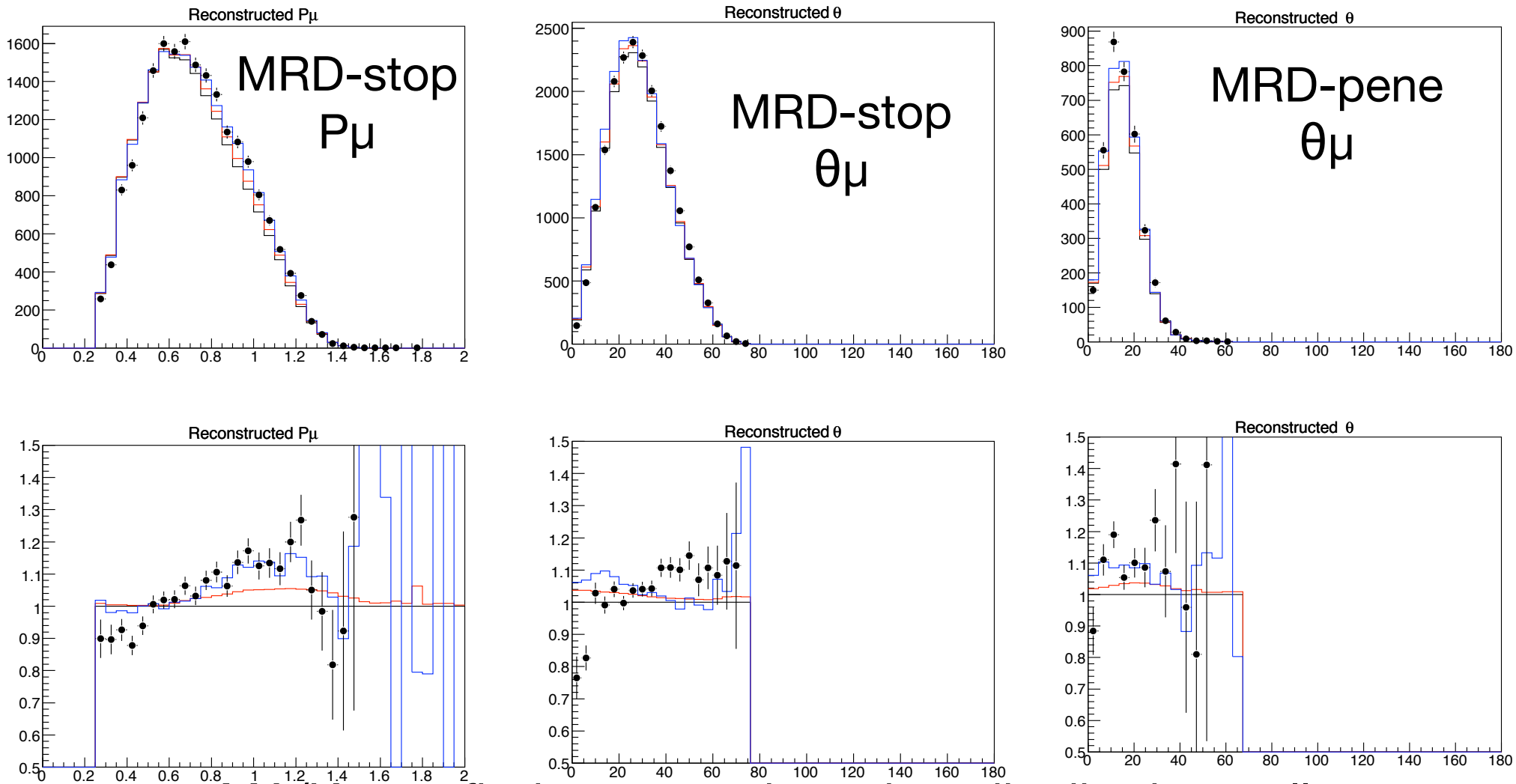
MA/Kappa simultaneous fit

	E_ν only		$E_\nu + M_A^{QE}/\kappa$	
	value	error	value	error
f_0	1.40	0.209	1.12	0.203
f_1	1.36	0.084	1.19	0.119
f_2	1.33	0.051	1.26	0.083
f_3	1.31	0.066	1.33	0.076
f_4	1.20	0.075	1.20	0.083
f_5	0.84	0.062	0.84	0.063
M_A^{QE}	1.234	Fixed	1.298	0.086
kappa	1.022	Fixed	1.016	0.0055
	chi2 = 201/153		chi2 = 206/151	

- Remove the MA/kappa error and allow MA/kappa to vary.
- Successfully find the best fit MA/kappa and the scale factors.
- Chi2 = 206/151
  - Become worse because the original MA/kappa errors are removed.

Distribution After Fit

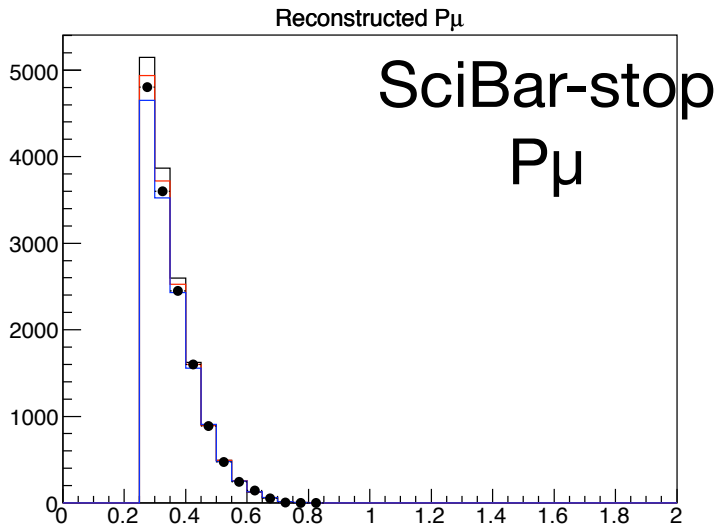
-- old Enu only fit
-- new Enu only fit (w/ proton error)
-- Enu and MA/Kappa fit

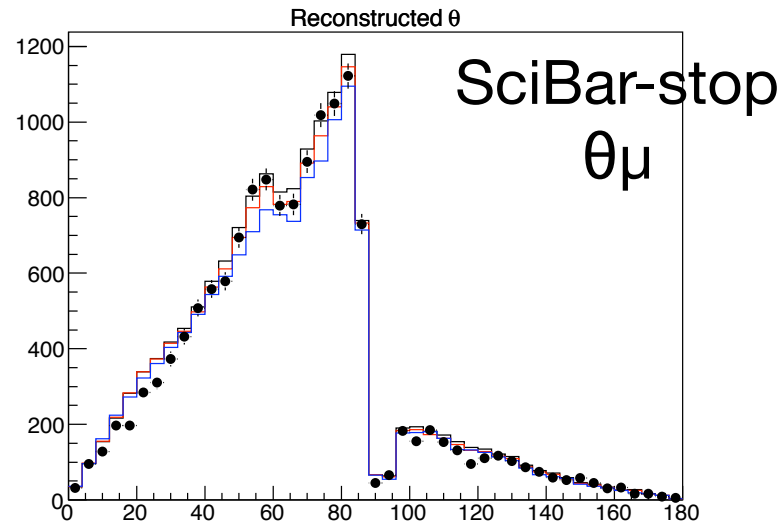


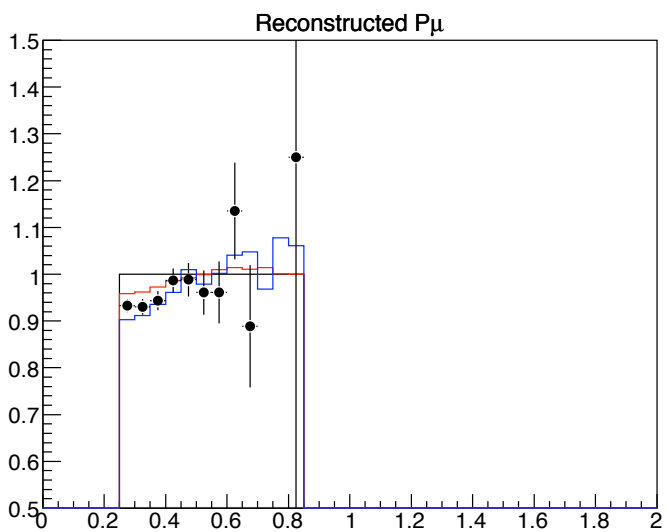
MA/Kappa fit does reproduce data distribution well,
except for muon angle in MRD-stopped....

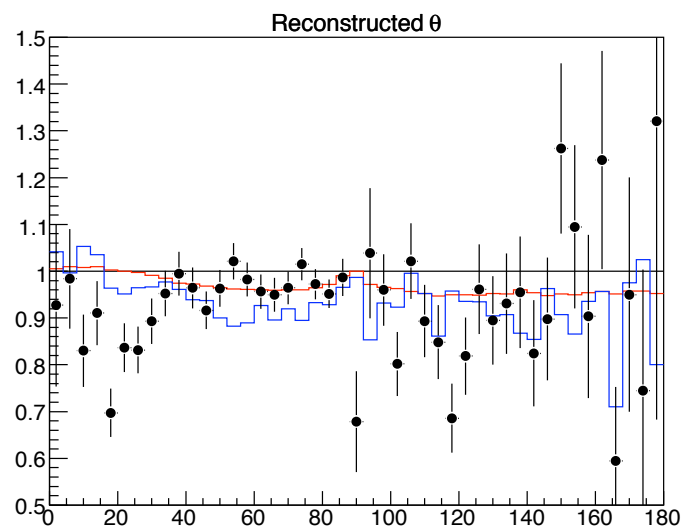
Distribution After Fit

-- old Enu only fit
-- new Enu only fit (w/ proton error)
-- Enu and MA/Kappa fit





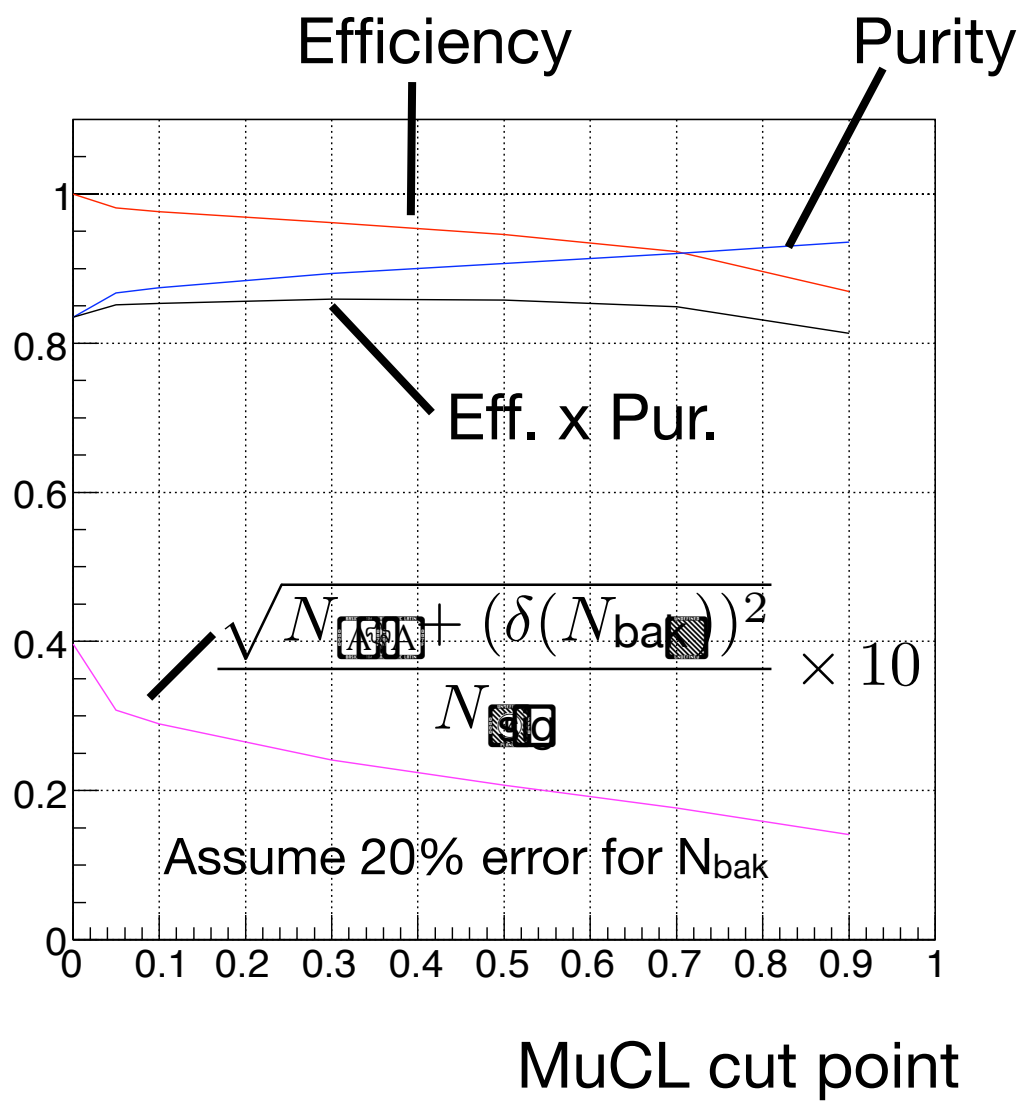




Spectrum (and MA/kappa) Fit with tighter MuCL requirement

Efficiency and Purity

MRD-stopped

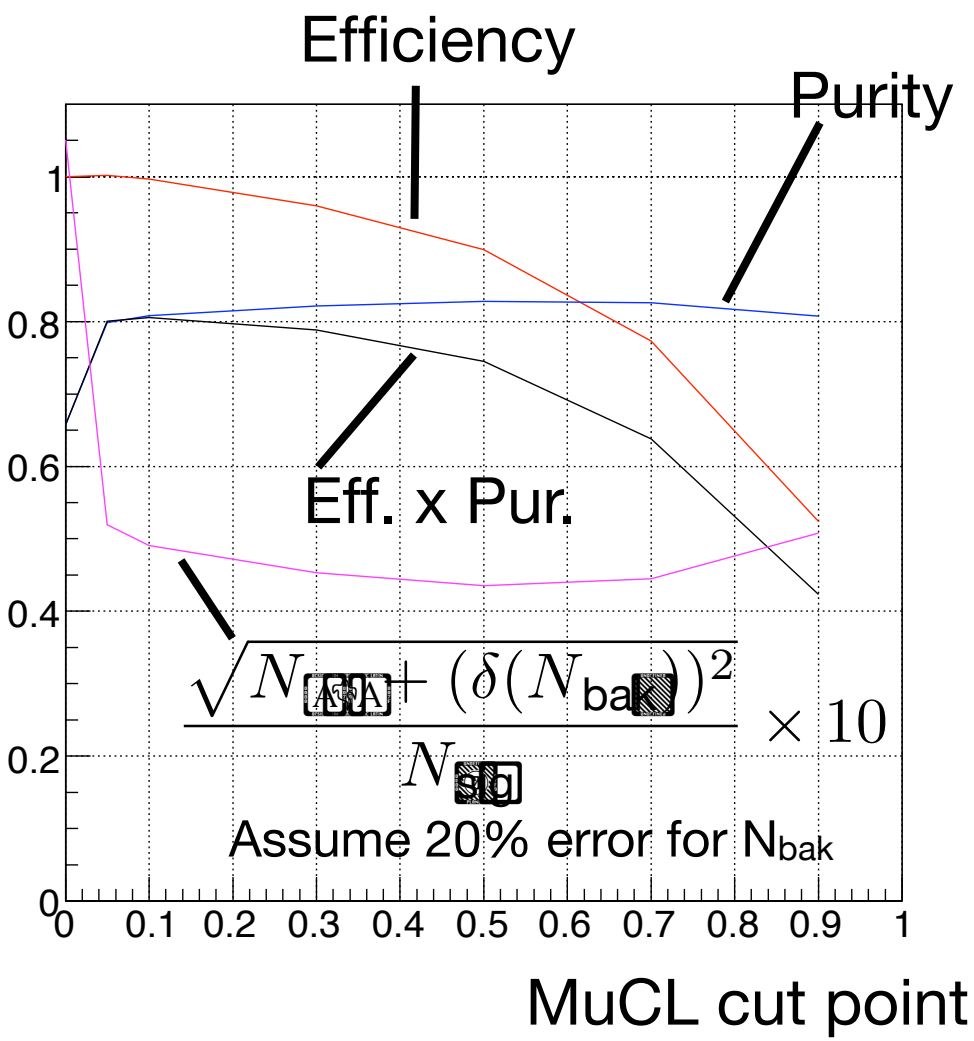


- Signal (MuCL): True CC events with correctly reconstruct muons.
- Efficiency:
  - Signal(x) /Signal(0)
- Purity: Signal(x)/Total(x)

- Eff x Pur becomes maximu at MuCL~0.3.
- However, if we assume 20% error for background contamination, the larger MuCL cut value is better.

Efficiency and Purity

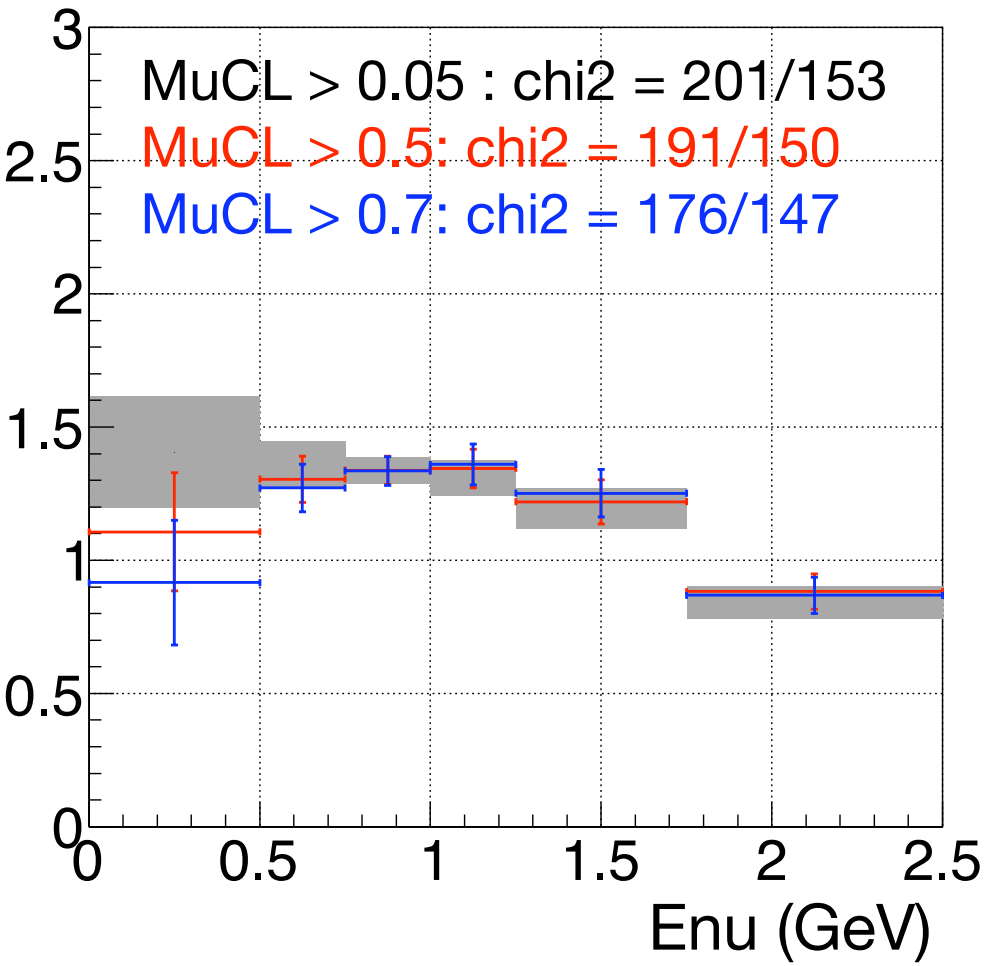
SciBar-stopped



- Since the muon momentum of SciBar-stopped sample tend to be low, the efficiency significantly drop at large MuCL value.
- Realistically, cut at somewhere around 0.3-0.7?

Spectrum Fit with different MuCL requirements

Fit with Enu only (MA/kappa are fixed)
Added new proton error.



- The chi2 values improved:
  - The source of the discrepancy exists at low-MuCL region?
- The normalization at low-Enu region changes significantly.
  - Still trying to understand

MA/Kappa simultaneous fit for MuCL > 0.5

	E_ν only		$E_\nu + M_A^{QE}/\kappa$	
	value	error	value	error
f_0	1.11	0.221	0.71	0.199
f_1	1.30	0.087	1.03	1.19
f_2	1.34	0.052	1.20	0.084
f_3	1.34	0.072	1.38	0.083
f_4	1.22	0.083	1.26	0.100
f_5	0.88	0.066	0.89	0.070
M_A^{QE}	1.234	Fixed	1.353	0.091
kappa	1.022	Fixed	1.011	0.0064
	chi2 = 191/150		chi2 = 195/148	

- Similar tendency as MuCL > 0.05 sample.
- However, the normalization factor at low-E is significantly small.
  - Found data-excess at SB-stopped sample (see backup slides)
- Bug? / Effect of systematic error?
- Under investigation

Summary

- SciBooNE spectrum fit update:
  - Proton tracks miss-identified as muon are found to be a large source of systematic uncertainty.
    - This error is implemented and improved the fit result.
    - However, chi2 is after fit is still not so good.
  - Tried tightening MuCL cut.
    - Found bit strange behavior.
    - Under investigation.
  - Working on resolving other sources of data/MC discrepancy.
- Plan:
  - Finish up the second half of the spectrum fit technote, and finalize the SciBooNE spectrum analysis, in a coming few weeks.

Extra Slides

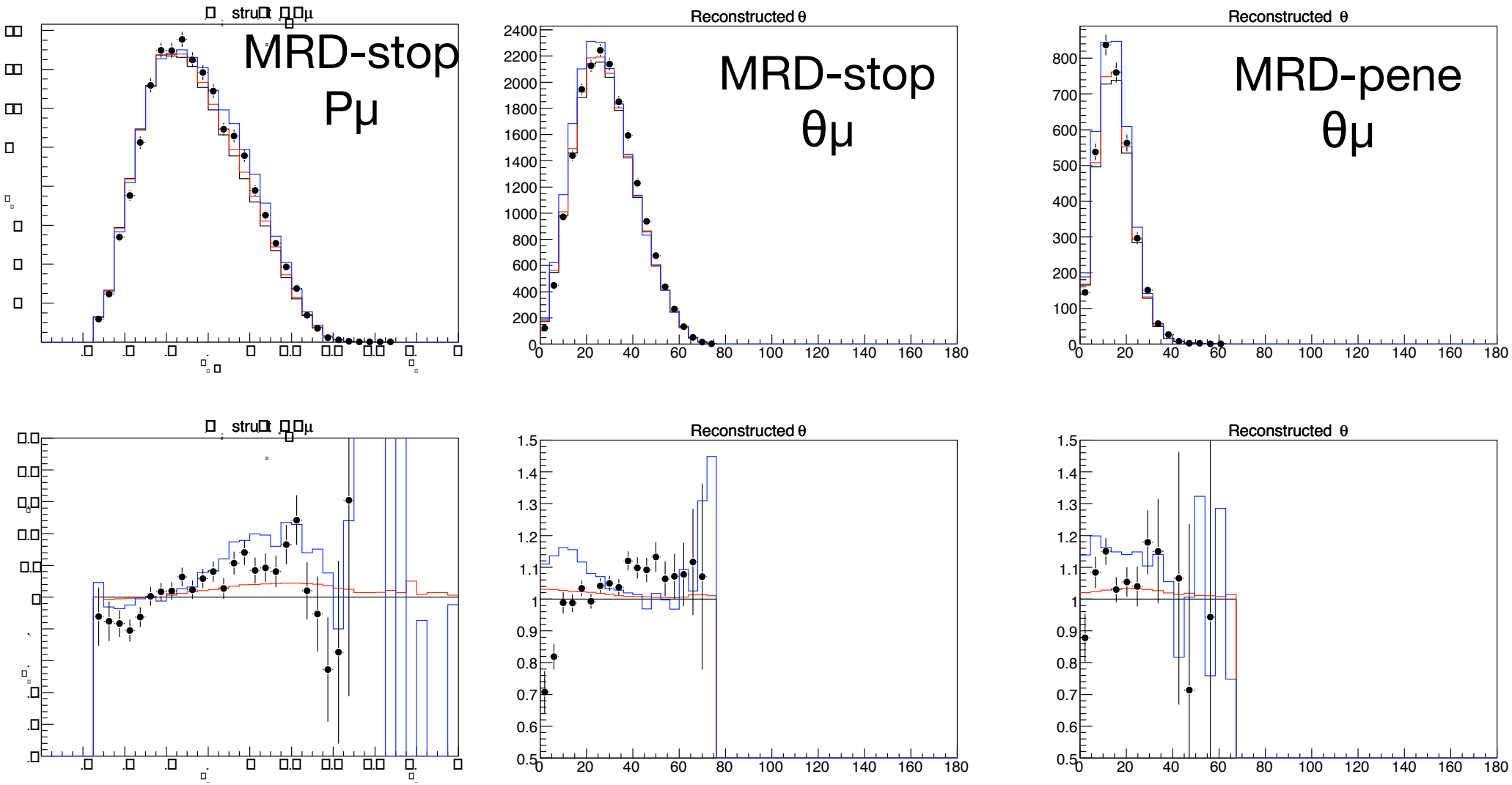
Distribution After Fit

Sample with MuCL >0.5

-- old Enu only fit

-- new Enu only fit (w/ proton error)

-- Enu and MA/Kappa fit



Distribution After Fit

Sample with MuCL >0.5

-- old Enu only fit

-- new Enu only fit (w/ proton error)

-- Enu and MA/Kappa fit