# Progress with Beam Fits

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Aug 12th , 2011, Beam Systematics group

# Selection cuts

Beam fits files are separated to NuMu and NuBar collections. Events preselected with:

- CC0720Std for FHC NuMu files
- Bravo for FHC NuBar files
- RHC0350 for Run4/7 (RHC) for both signs.
- R2.7 release used for most of the sets. See also p3.

Also reduced the number of POTs to be used in the fit for several Data and MC sets – that improved the timing of the fit jobs, which is important at this stage.

# NuMu events statistics (in POTs)

Note: Run7 ME and HE are not used in all fits in this Doc

Data

NuMu/l010z000i_run1/PoT = 2.5132e+18
NuMu/l010z000i_run2/PoT = 2.3879e+18
NuMu/l010z000i_run3/PoT = 6.3621e+18
NuMu/l010z170i_run1/PoT = 1.3920e+18
NuMu/l010z185i_run1/PoT = 2.3084e+18
NuMu/l010z185i_run2/PoT = 4.1416e+18
NuMu/l010z185i_run3/PoT = 4.0403e+18
NuMu/l010z185i_run4/PoT = 9.0783e+18
NuMu/l010z185i_run7/PoT = 9.3769e+18
NuMu/l010z200i_run1/PoT = 1.3263e+18
NuMu/l100z200i_run1/PoT = 0.8563e+18
NuMu/l100z200i_run7/PoT = 1.3340e+18 //r2.5
NuMu/l150z200i_run2/PoT = 0.7794e+18
NuMu/l250z200i_run1/PoT = 1.4014e+18
NuMu/l250z200i_run7/PoT = 0.8080e+18 //r2.5

MC

NuMu/l010z000i_run1/PoT = 6.1294e+18
NuMu/l010z000i_run2/PoT = 5.5209e+18
NuMu/l010z000i_run3/PoT = 8.3311e+18
NuMu/l010z170i_run1/PoT = 3.2718e+18
NuMu/l010z185i_run1/PoT = 7.6877e+18 //r2.2
NuMu/l010z185i_run2/PoT = 8.4486e+18 //r2.2
NuMu/l010z185i_run3/PoT = 9.6564e+18 //r2.2
NuMu/l010z185i_run4/PoT = 7.5636e+18
NuMu/l010z185i_run7/PoT = 7.5240e+18
NuMu/l010z200i_run1/PoT = 3.3686e+18
NuMu/l100z200i_run1/PoT = 1.6598e+18
NuMu/l100z200i_run7/PoT = 1.6188e+18 //r2.5
NuMu/l150z200i_run2/PoT = 1.4136e+18
NuMu/l250z200i_run1/PoT = 1.6781e+18
NuMu/l250z200i_run7/PoT = 1.6074e+18 //r2.5

Some of data/MC were obtained with previous cuts/test releases. I will redo the fit with the "correct" files, as soon as those input DSTs available.

# NuBar events statistics (in POTs)

Note: Run7 ME and HE are not used in all fits in this Doc

| Data | MC |
|---|---|
| NuMuBar/l010z000i_run1/PoT = 2.5132e+18 | NuMuBar/l010z000i_run1/PoT = 1.22975e+19 |
| NuMuBar/l010z000i_run2/PoT = 2.3871e+18 | NuMuBar/l010z000i_run2/PoT = 1.21378e+19 |
| NuMuBar/l010z000i_run3/PoT = 6.3621e+18 | NuMuBar/l010z000i_run3/PoT = 1.72404e+19 |
| NuMuBar/l010z170i_run1/PoT = 1.3920e+18 | NuMuBar/l010z170i_run1/PoT = 3.2718e+18 |
| NuMuBar/l010z185i_run1/PoT = 1.12175e+19 | NuMuBar/l010z185i_run1/PoT = 1.60465e+19 |
| NuMuBar/l010z185i_run2/PoT = 1.86227e+19 | NuMuBar/l010z185i_run2/PoT = 1.67375e+19 |
| NuMuBar/l010z185i_run3/PoT = 1.45855e+19 | NuMuBar/l010z185i_run3/PoT = 2.03596e+19 |
| NuMuBar/l010z185i_run4/PoT = 2.15688e+19 | NuMuBar/l010z185i_run4/PoT = 1.57014e+19 |
| NuMuBar/l010z185i_run7/PoT = 1.84298e+19 | NuMuBar/l010z185i_run7/PoT = 1.51074e+19 |
| NuMuBar/l010z200i_run1/PoT = 1.3263e+18 | NuMuBar/l010z200i_run1/PoT = 3.3686e+18 |
| NuMuBar/l100z200i_run1/PoT = 1.1018e+18 | NuMuBar/l100z200i_run1/PoT = 3.3014e+18 |
| NuMuBar/l100z200i_run7/PoT = 3.2975e+18 //r2.5 | NuMuBar/l100z200i_run7/PoT = 3.8076e+18 //r2.5 |
| NuMuBar/l150z200i_run2/PoT = 1.8358e+18 | NuMuBar/l150z200i_run2/PoT = 3.0917e+18 |
| NuMuBar/l250z200i_run1/PoT = 4.2751e+18 | NuMuBar/l250z200i_run1/PoT = 3.3106e+18 |
| NuMuBar/l250z200i_run7/PoT = 1.9163e+18 //r2.5 | NuMuBar/l250z200i_run7/PoT = 3.1464e+18 //r2.5 |

# Reminder on Hadron Production Parameters

From Mark's docs

Target yields of secondaries have been parameterized according to:

$$\frac{d^2N}{dx_F dp_T} = [A + Bp_T] * \exp(-Cp_T^{3/2})$$

where A, B and C are functions of $x_F$.

- A: determines low $p_T$ yields
- B: determines how fast distribution rises
- C: determines high $p_T$ fall-off

- Consider linear warpings of A, B and C as $f(x_F)$:

$$A' = ([0]+[1]*x_F) * A$$
$$B' = \ldots$$

- Need 6 parameters for positives to construct:

$$W(ptype, p_T, x_F) = \frac{[A' + B'p_T] * \exp(-C'p_T^{3/2})}{[A + Bp_T] * \exp(-Cp_T^{3/2})}$$

- Need 2 parameters for negatives to construct:

$$W^- = ([0]+[1]*x_F) * W^+$$

***Hadron production ratios as f($p_z$) are penalized in penalty term.***

**6 pi+, 6 K+, 2 pi- and 2 K- parameters.**

16 in total

# Beam input parameters

'horn_1_offset ( 0.0 0.5 -5. 5. 1.) fix',
'baffle ( 0.0 0.5 -5. 5. 1.) fix',
'pot ( 0.0 0.5 -5. 5. 1.) fix',
'horn_I_miscal ( 0.0 0.5 -15. 15. 100.)',
'horn_I_dist. ( 0.0 0.5 -15. 15. 100.)',
'TgtZ_le10 ( 0.30 0.0 -10. 10. 1.)fix',
'TgtZ_le100 ( 0.30 0.0 -10. 10. 1.)fix',
'TgtZ_le150 ( 1.90 0.0 -10. 10. 1.)fix',
'TgtZ_le250 ( 0.30 0.0 -10. 10. 1.)fix',
'TgtZ_le10N ( 0.80 0.0 -10. 10. 1.)fix',
'TgtZ_le250N ( 1.90 0.0 -10. 10. 1.)fix',
'TgtZ_le10R3 ( 0.80 0.0 -10. 10. 1.)fix',
'TgtZ_le10R4 ( 0.60 0.0 -10. 10. 1.)fix',
'TgtZ_special ( 0.40 0.0 -10. 10. 1.)fix',
'TgtZ_le10R7 ( 1.15 0.0 -10. 10. 1.)fix',
'TgtDecayN ( 8.25854e-01 0.5 -10. 10. 1.)fix',
'TgtDecayR3 ( 2.81222e+00 0.5 -10. 10. 2.)fix'

Accounts for the shifts between surveyed beam Z pos and nominal MC Z pos.

Added recently

Accounts for target decay

# Detector input parameters

- 'miscal ( 1.93681e-02 0.01 -0.5 0.5 0.05)',
- 'miscalnue ( 0.000 0.0 -0.5 0.5 0.05) fix',
- 'shwoff ( 0.000 9.83815e-05 -1.0 1.0 0.05)fix',
- 'ncnumu ( -3.81815e-01 1.16209e-01 -0.9 0.9 0.3 )', //Note negative input
- 'ncnumubar ( 2.51376e-01 2.44248e-01 -0.9 0.9 0.3 )',
- 'ncnue ( 0.00000e+00 constant -0.9 0.9 0.3 ) fix',
- 'numubarPar1 ( 1.050 2.19363e-02 0. 3. 0. )', //nubar xSec par
- 'numubarPar2 ( 2.50000e+01 constant 20. 30. 0. ) fix',
- 'miscaleshw ( 0.000 3.28324e-02 -3.0 3.0 1.0 )fix',
- 'emurange ( 0.000 2.39240e-03 -0.3 0.3 0.02)fix',
- 'xsqema ( 0.000 0.70324e-01 -10.0 10.0 1.5 )fix',
- 'xsresma ( 0.000 0.38088e-01 -10.0 10.0 1.5 )fix',
- 'xskno ( 0.0 2.05895e-01 -10.0 10.0 1.0 ) fix'

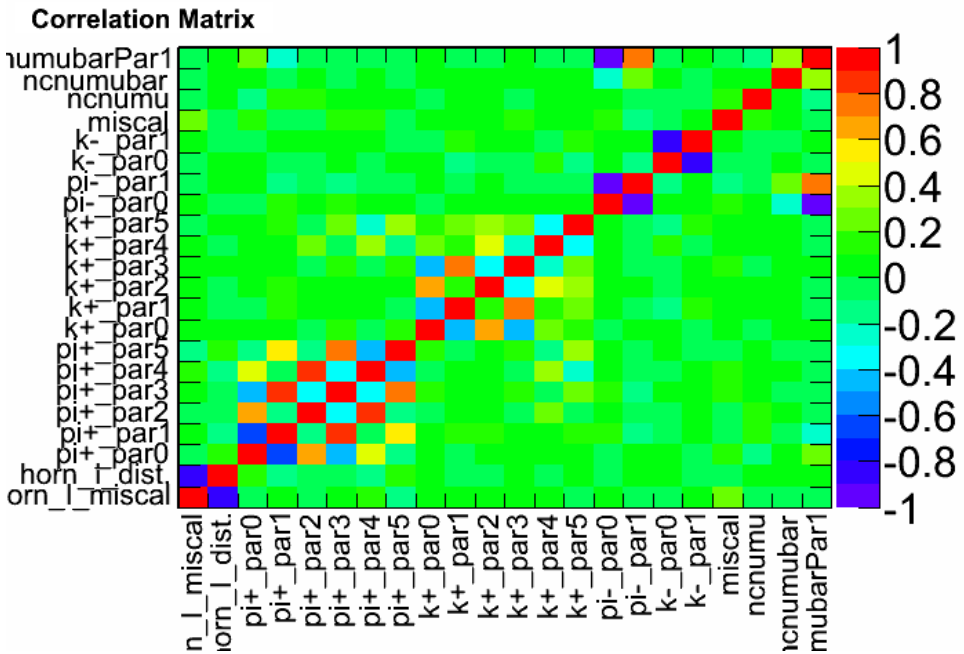
# Fit configurations:

I made several fits with different config:

- Fluka 5% constrains, no NA49, all LE,HE + RHC (FL5)
- Fluka 5% constrains, no NA49, all RHC only (FL5)
- NA49 5% to pi+/pi-, 60% to K+/K-, Fluka 7% to K/pi (5-60-FL7-FL7)
- NA49 5% to pi+/pi-, 4% to K+/K-, Fluka 7% to K/pi (5-4-FL7-FL7)
- the same as above for all + RHC
- the same, but only RHC
- the same, but only for all, no RHC
- the same, but only LE + RHC

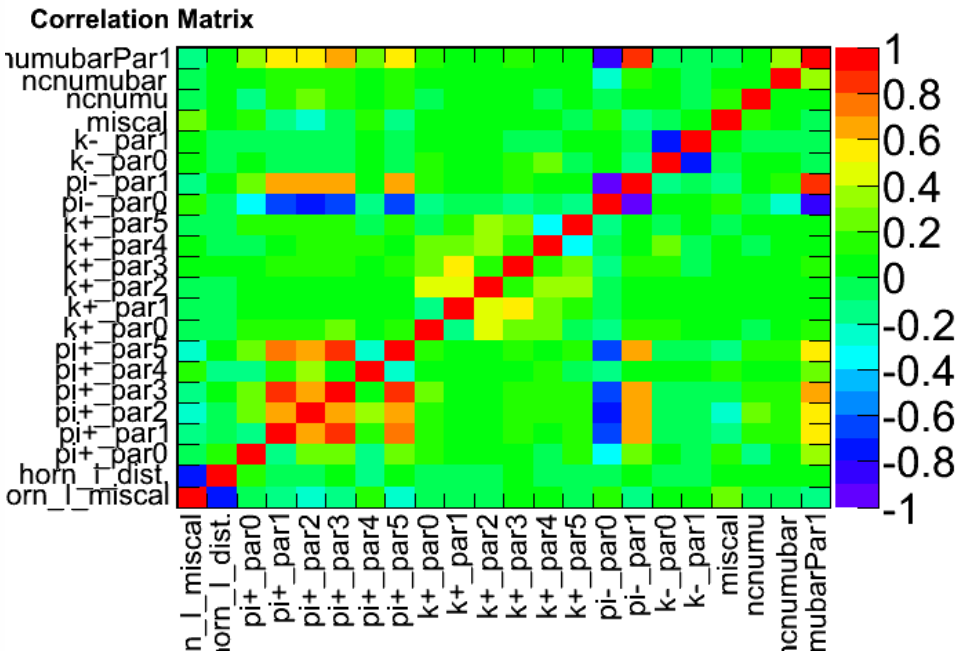
# Some fit param correlations plots

Fluka 5%, no NA49, no Run7




Chi2= 2141/1474=1.45

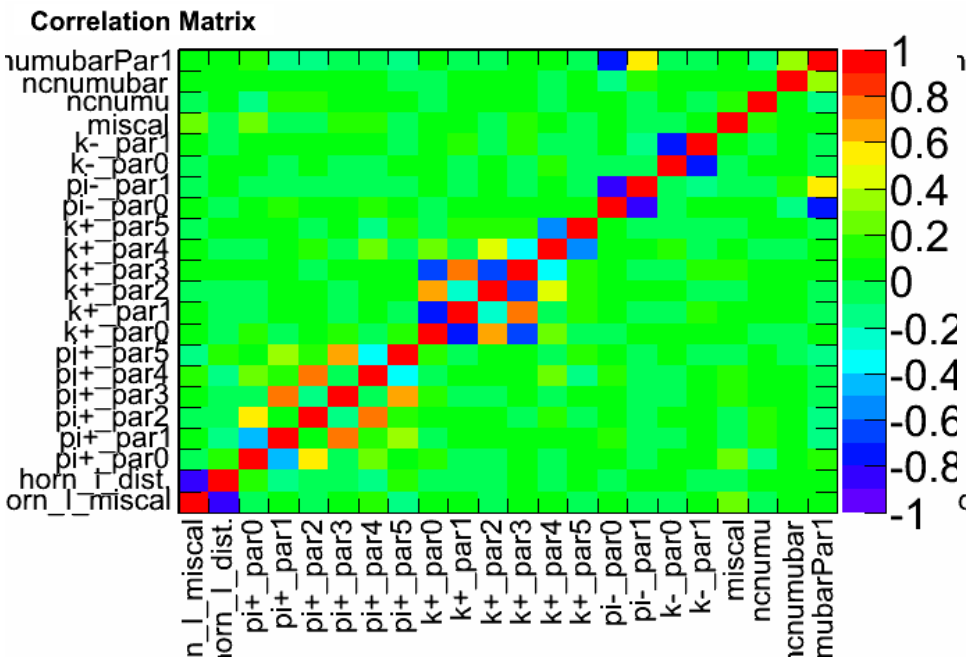
5-60-FL7-FL7




Chi2=2078/1474=1.41

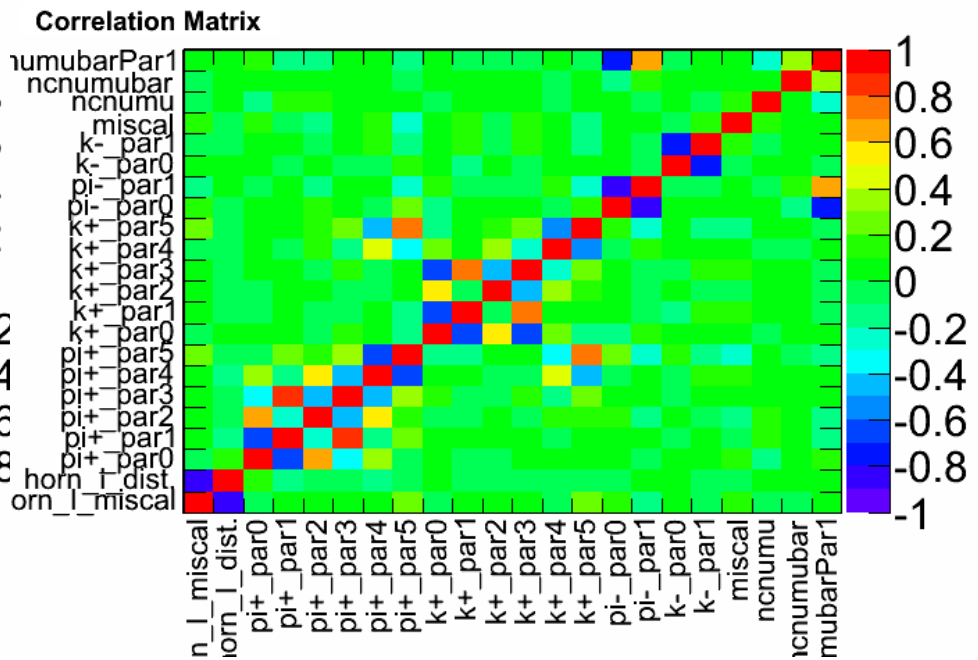
# Some fit param correlations -2

5(NA)-4(NA)-7(FL)-7(FL), all + RHC



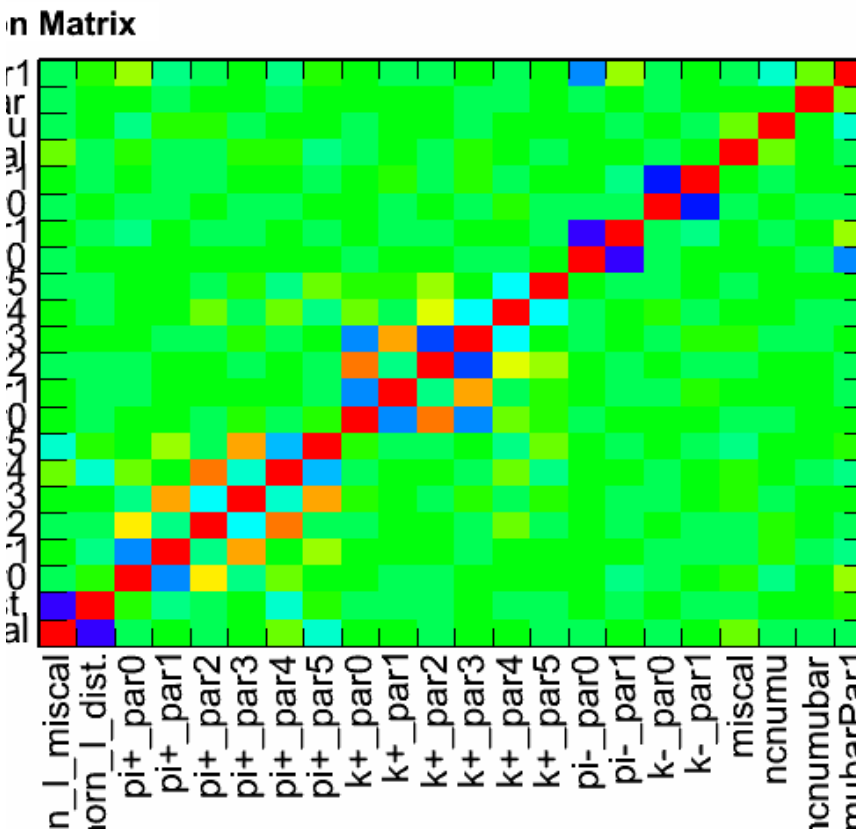

Chi2=2104/1474=1.43

5(NA)-4(NA)-7(FL)-7(FL), LE+RHC



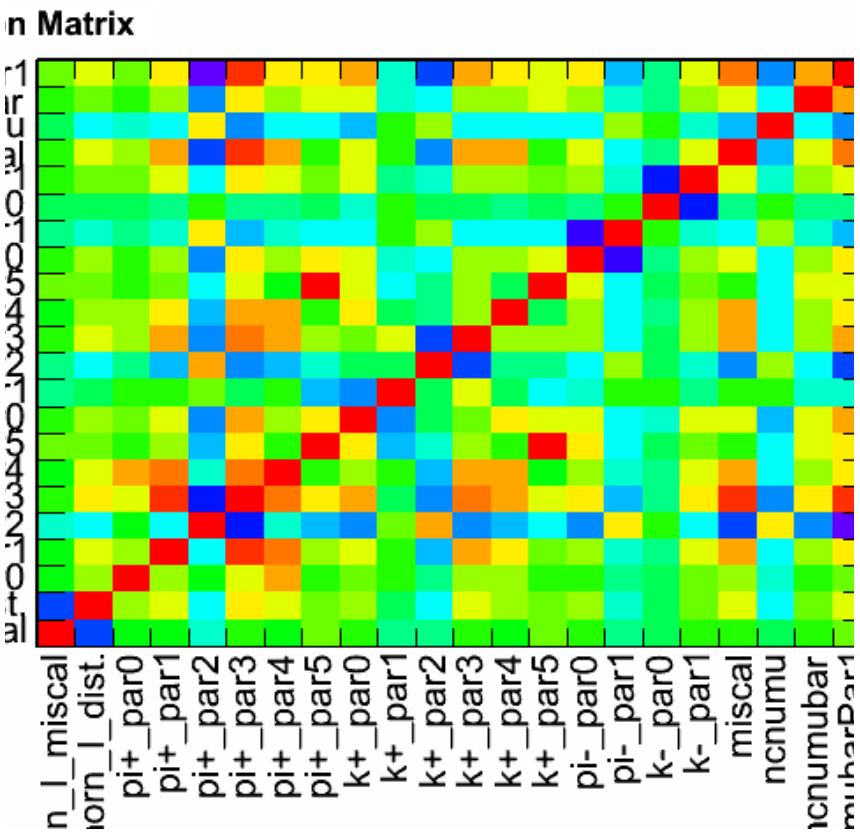

Chi2=1714/1163=1.47

## 5-4-FL7-FL7, no RHC




Chi2= 1655/1198=1.38

## 5-4-FL7-FL7, RHC only

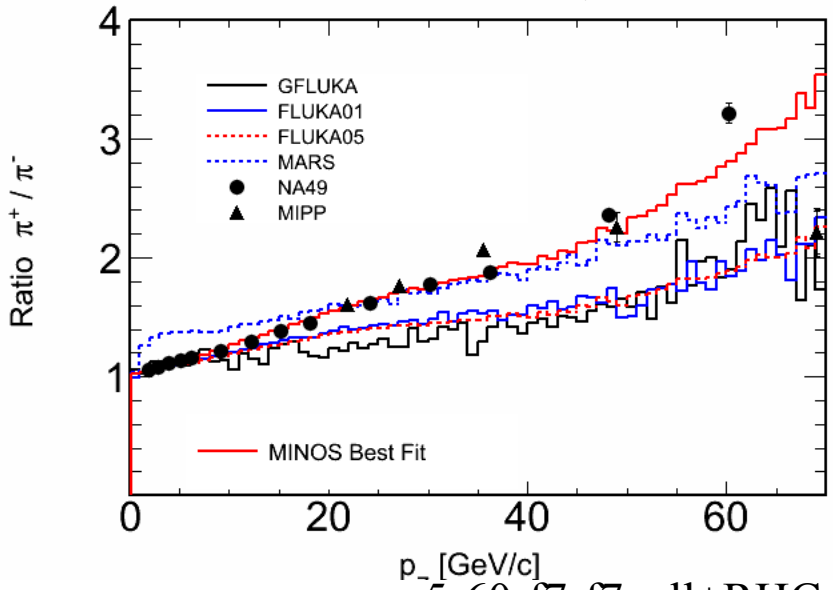



Chi2=357/276=1.29

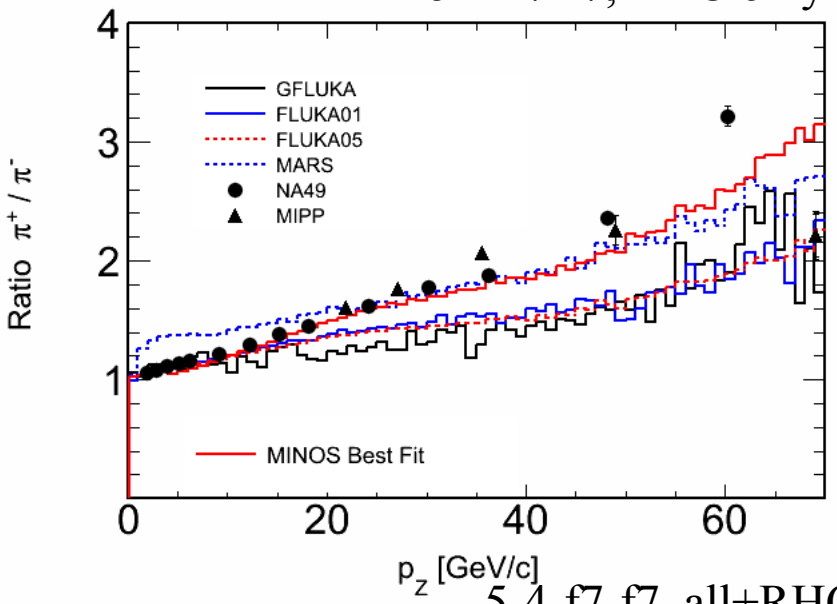
# Hadron yields ratios

# $\pi^+/\pi^-$

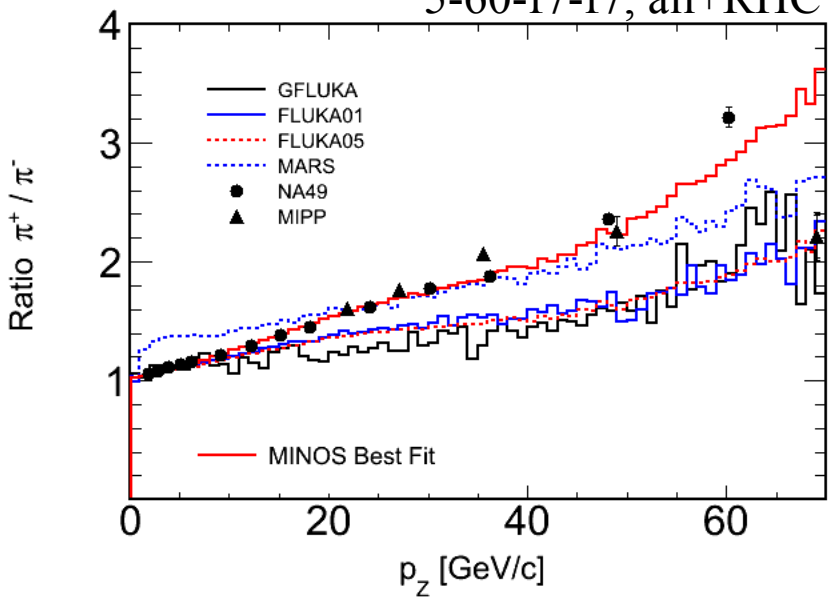
Fluka 5%, No NA49



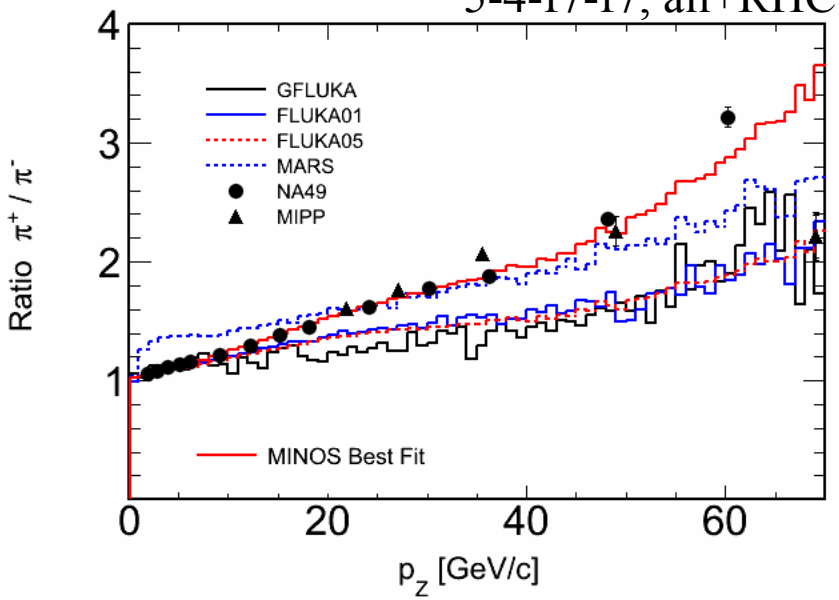

5-4-f7-f7, RHC only




5-60-f7-f7, all+RHC

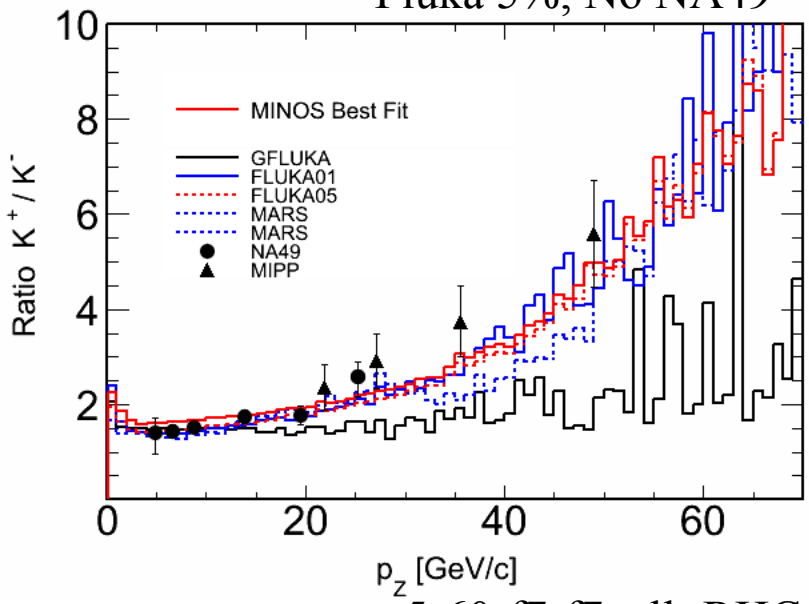



5-4-f7-f7, all+RHC

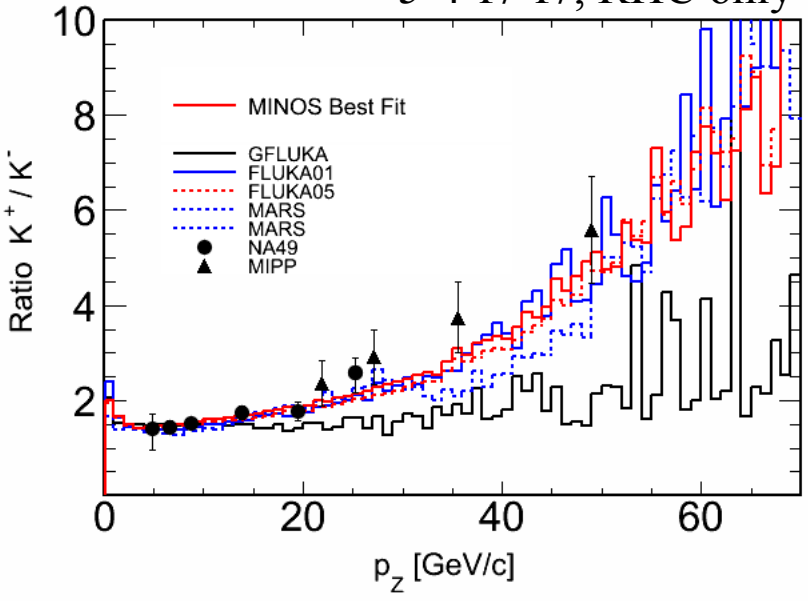


# $K^+/K^-$

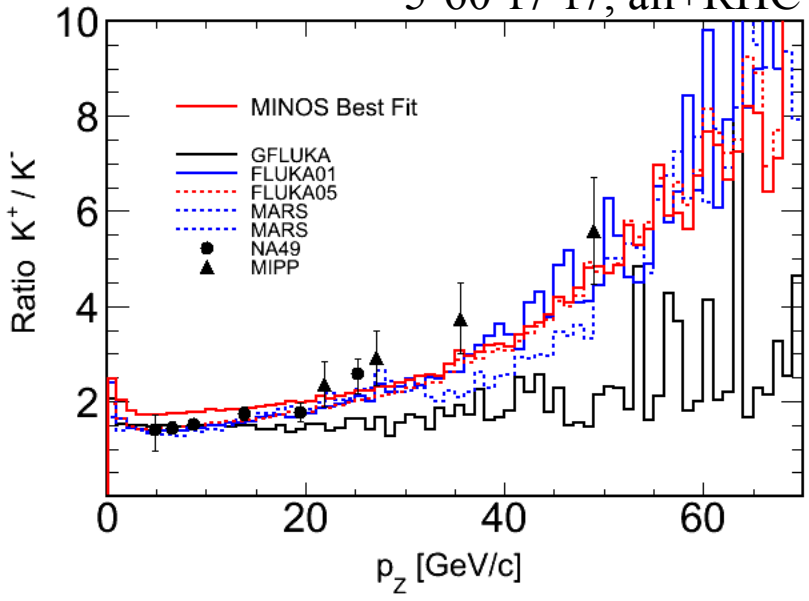
Fluka 5%, No NA49



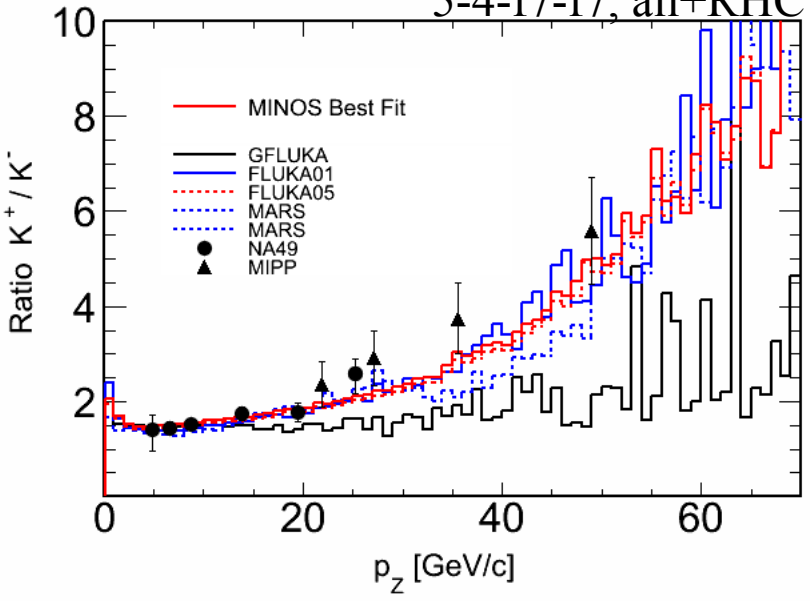

5-4-f7-f7, RHC only




5-60-f7-f7, all+RHC

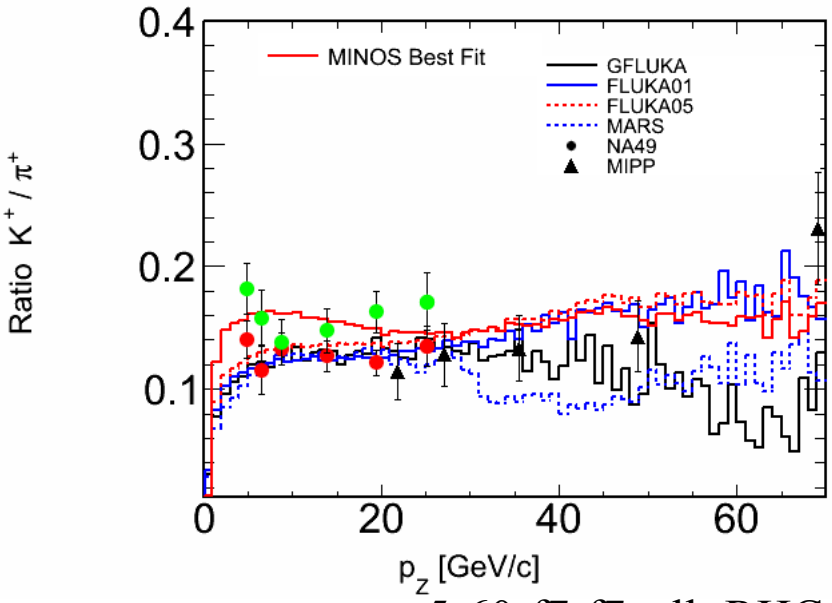



5-4-f7-f7, all+RHC

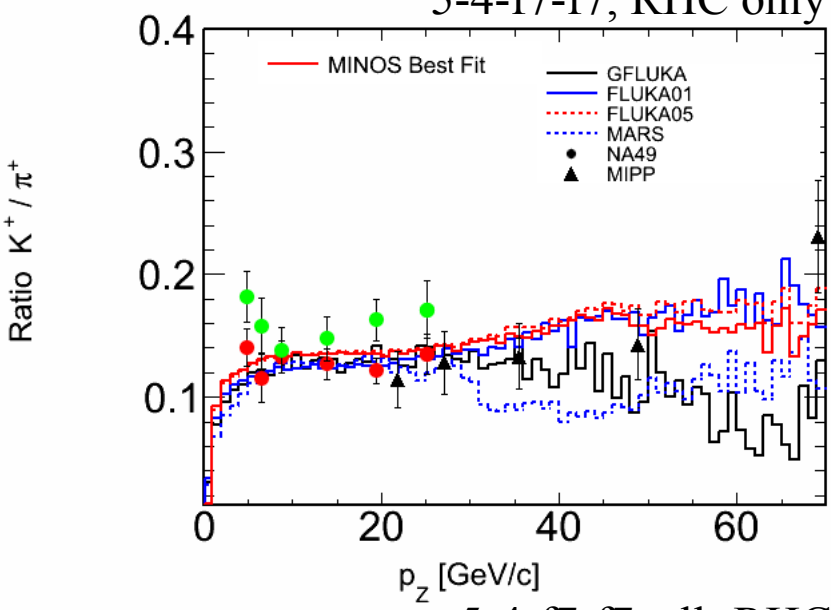


# $K^+/\pi^+$

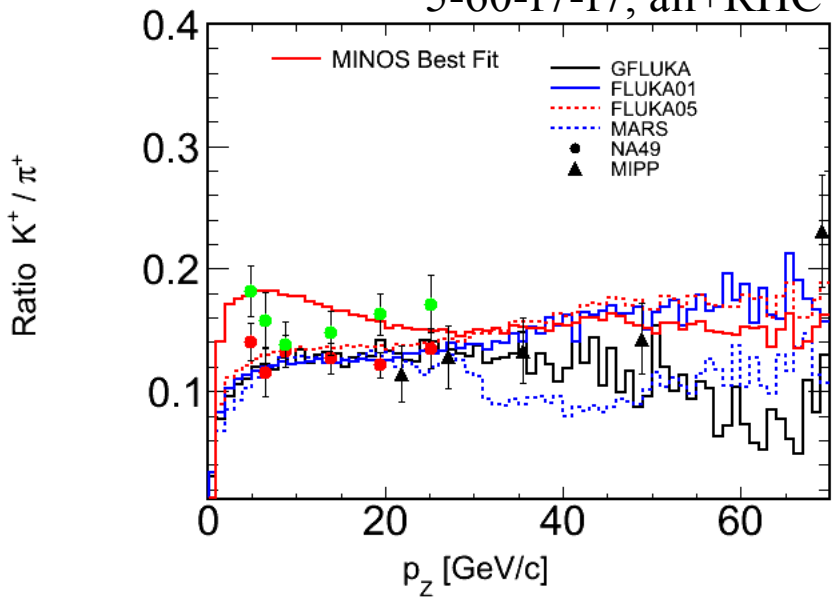
Fluka 5%, No NA49



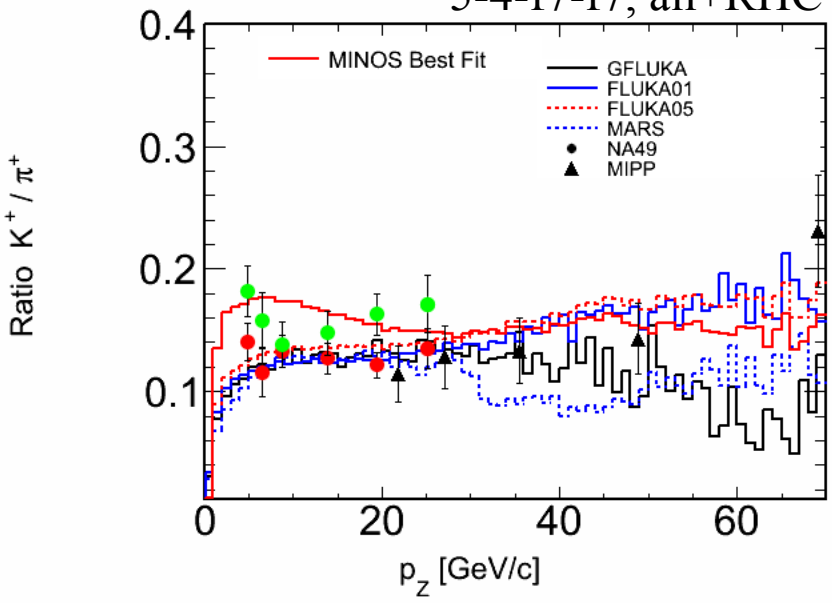

5-4-f7-f7, RHC only




5-60-f7-f7, all+RHC

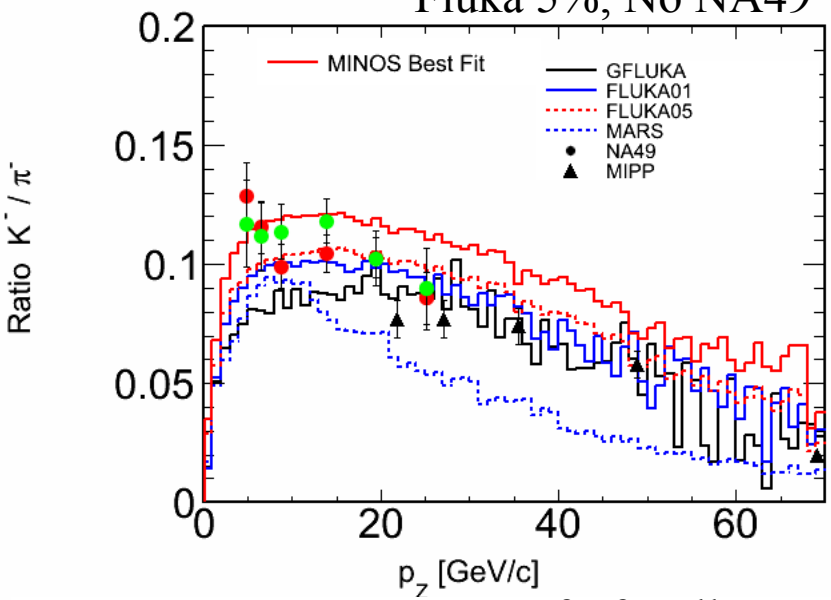



5-4-f7-f7, all+RHC

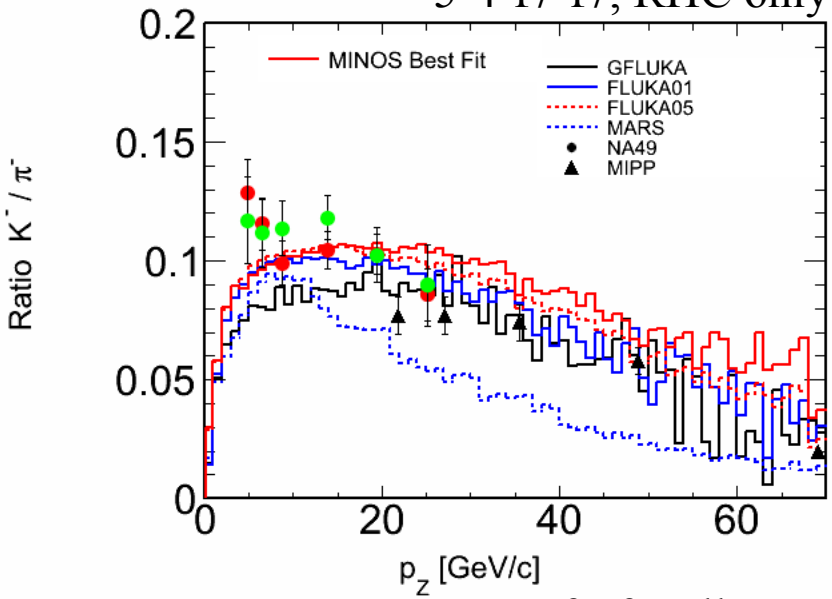


# $K^-/\pi^-$

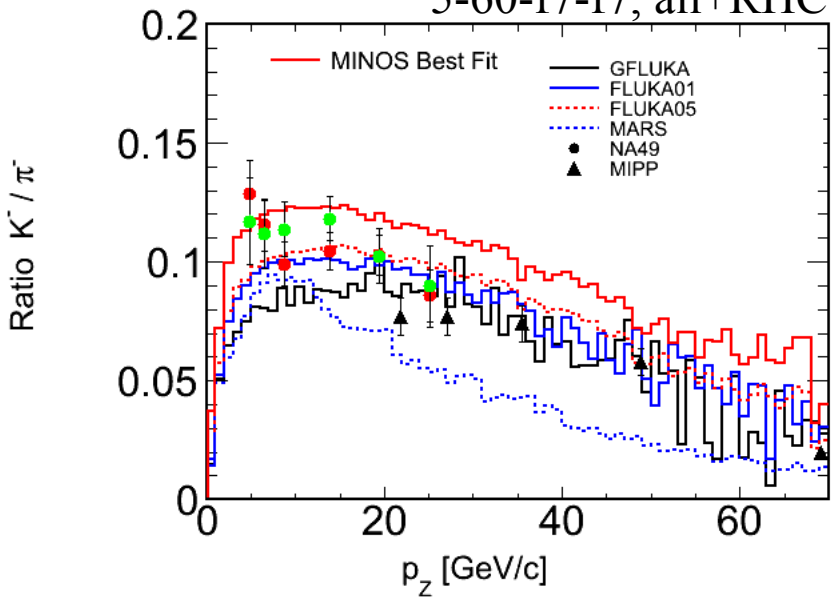
Fluka 5%, No NA49



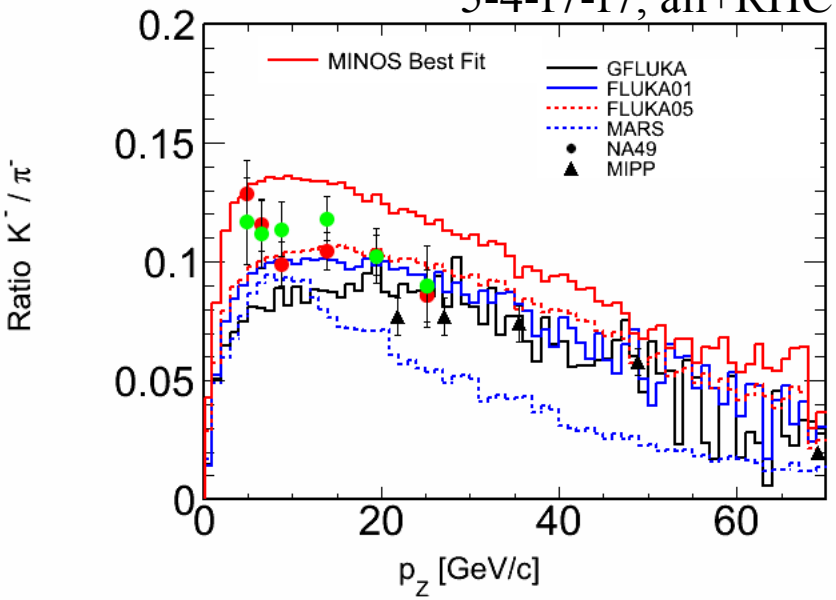

5-4-f7-f7, RHC only



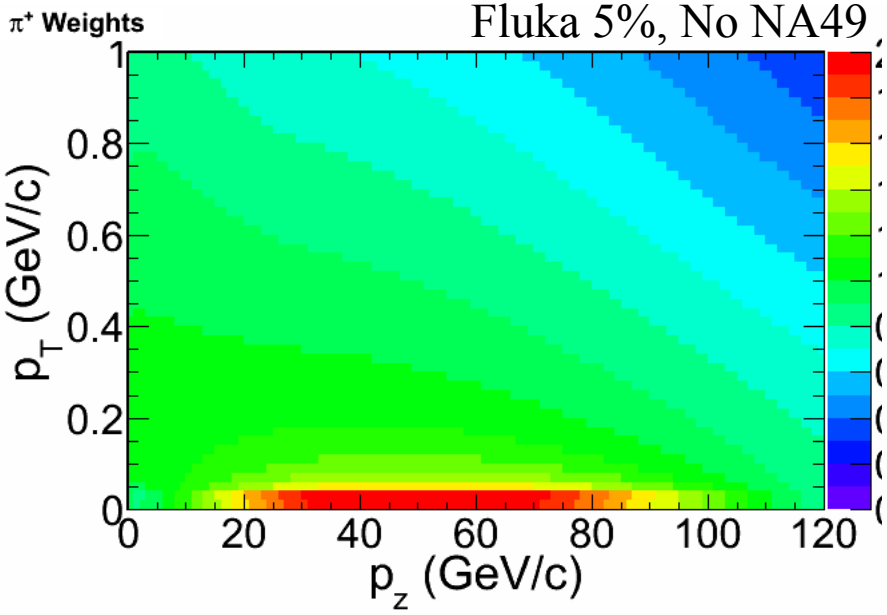

5-60-f7-f7, all+RHC

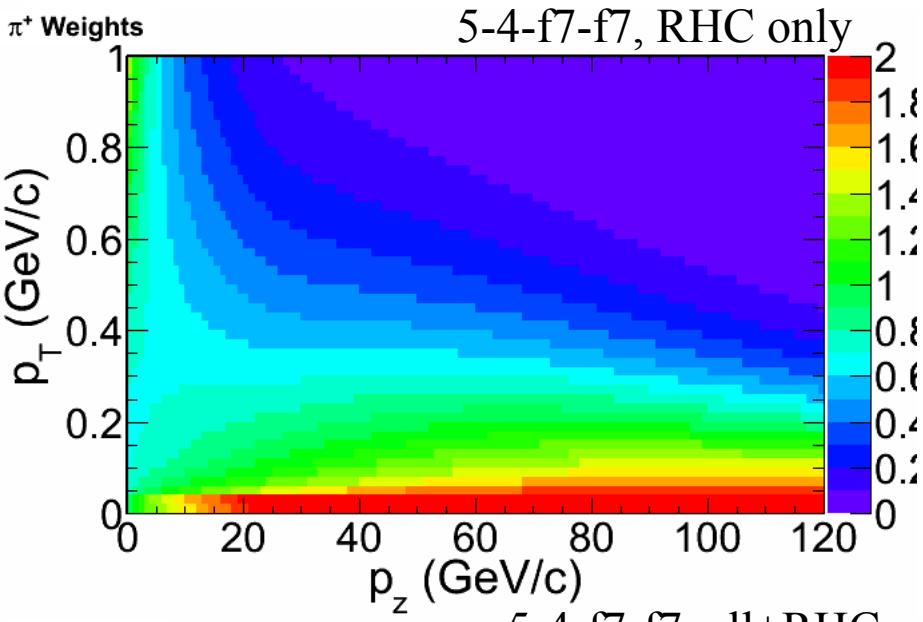


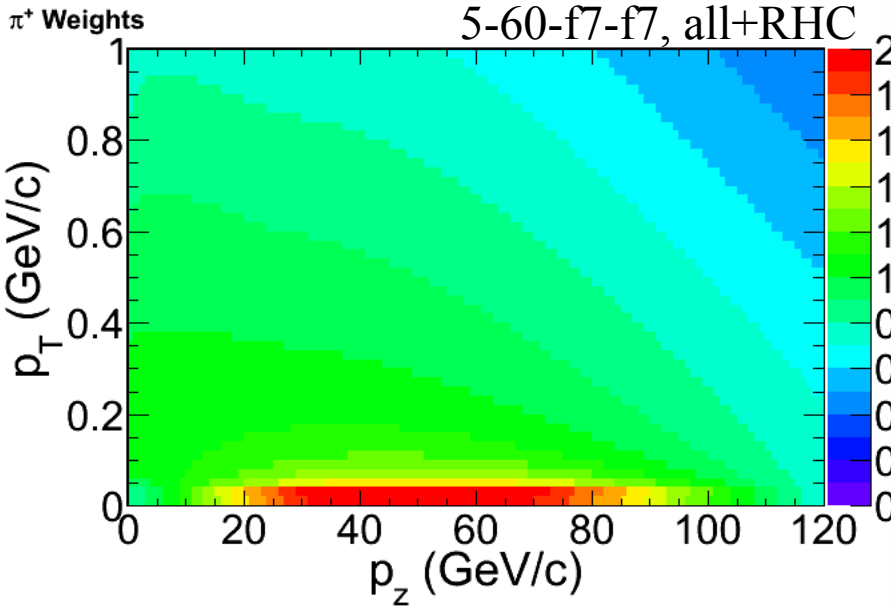

5-4-f7-f7, all+RHC

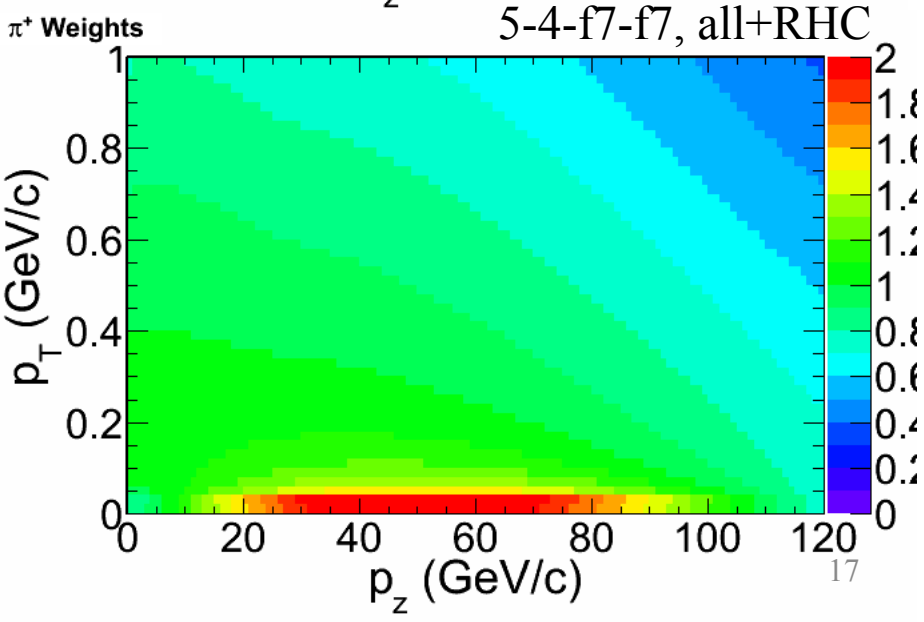


# $\pi^+$ weights

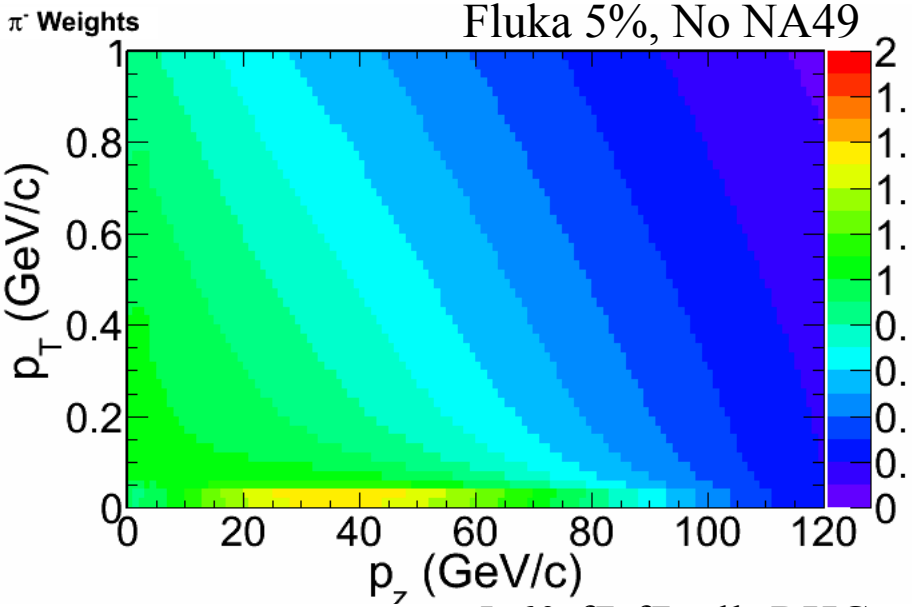

π⁺ Weights
Fluka 5%, No NA49
p_T (GeV/c)
p_z (GeV/c)

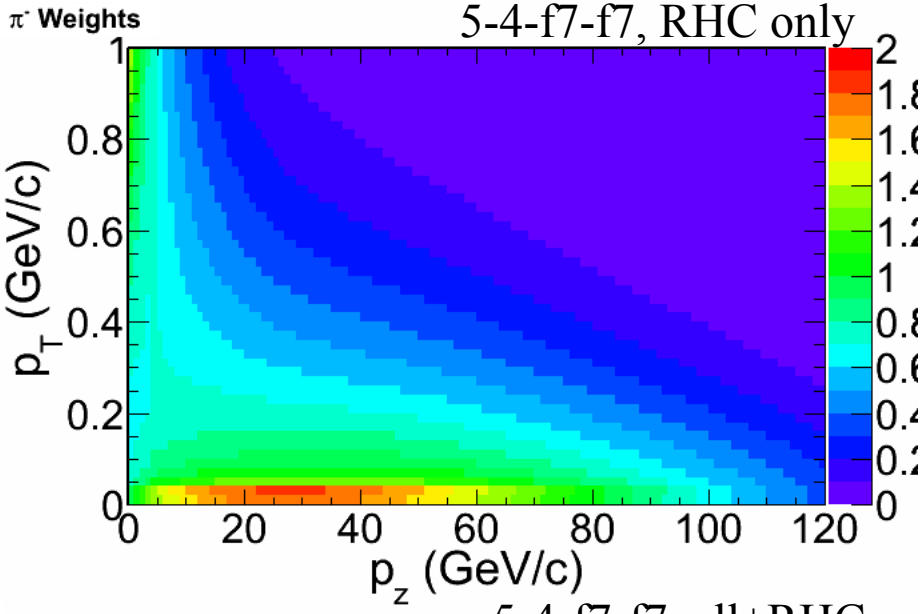

π⁺ Weights
5-4-f7-f7, RHC only
p_T (GeV/c)
p_z (GeV/c)

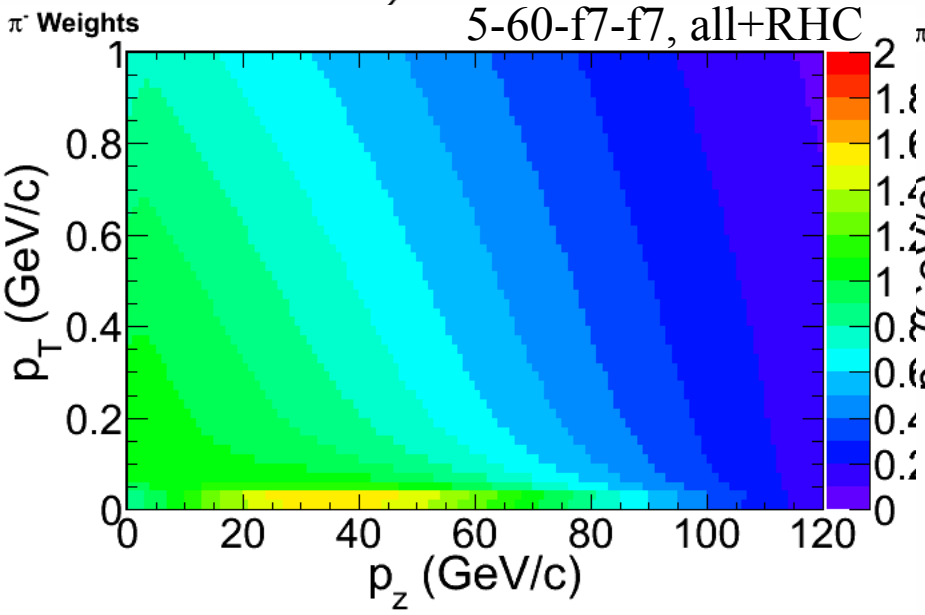

π⁺ Weights
5-60-f7-f7, all+RHC
p_T (GeV/c)
p_z (GeV/c)

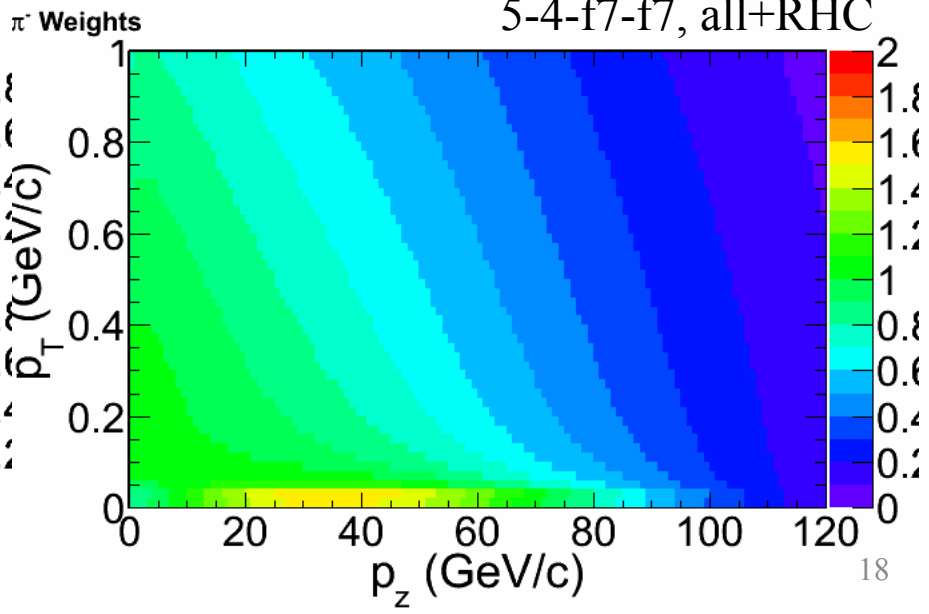

π⁺ Weights
5-4-f7-f7, all+RHC
p_T (GeV/c)
p_z (GeV/c)

# $\pi^-$ weights

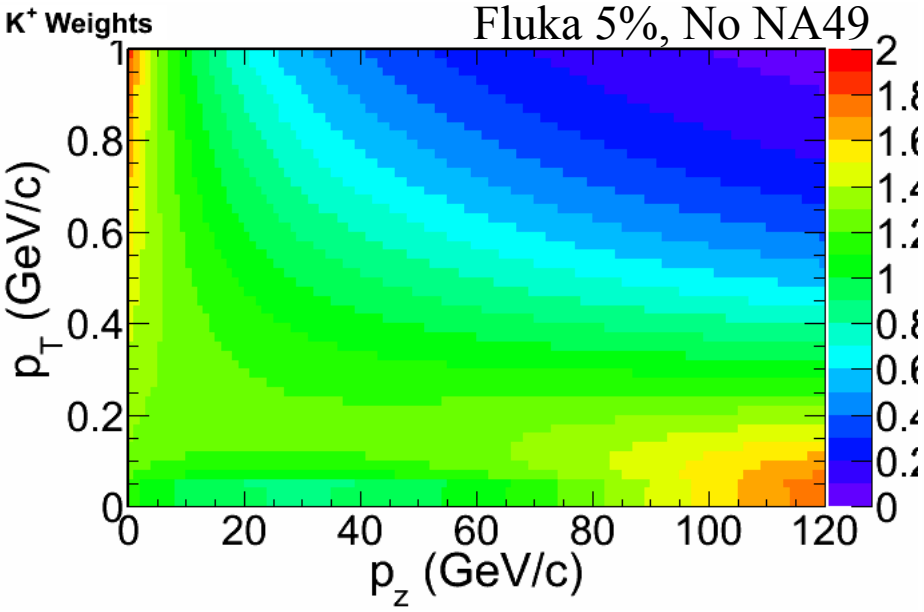

π⁻ Weights
Fluka 5%, No NA49
p_T (GeV/c)
p_z (GeV/c)

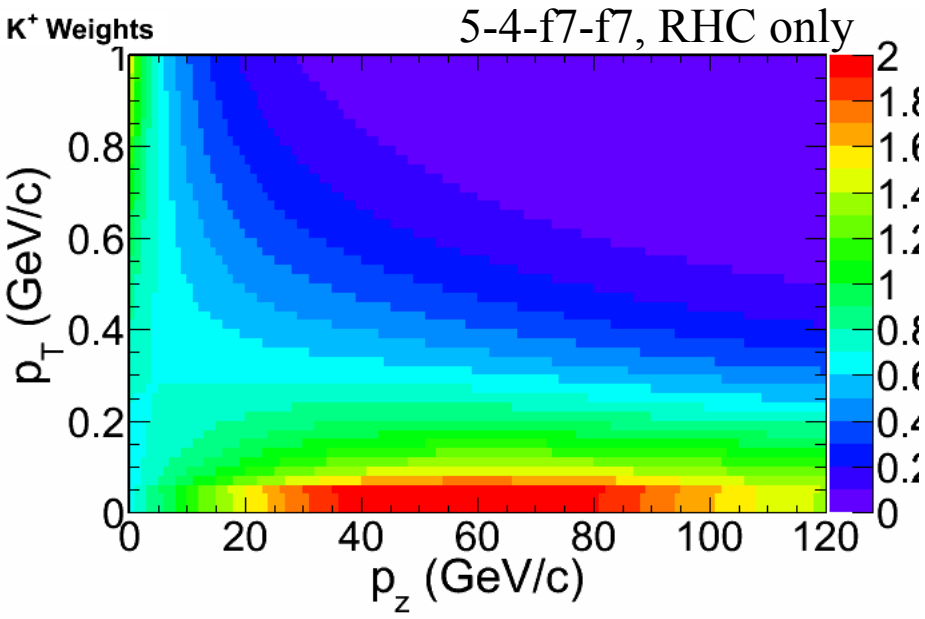

π⁻ Weights
5-4-f7-f7, RHC only
p_T (GeV/c)
p_z (GeV/c)

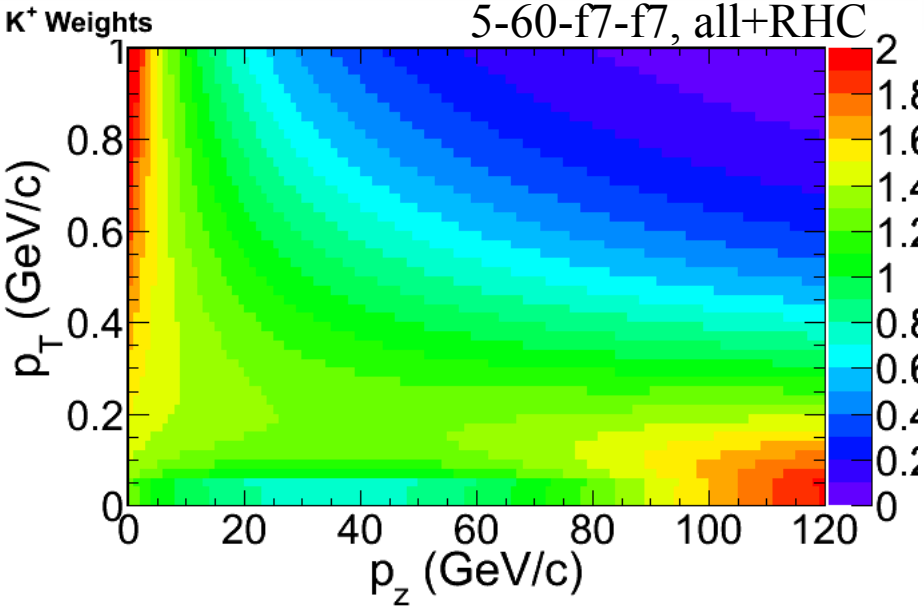

π⁻ Weights
5-60-f7-f7, all+RHC
p_T (GeV/c)
p_z (GeV/c)

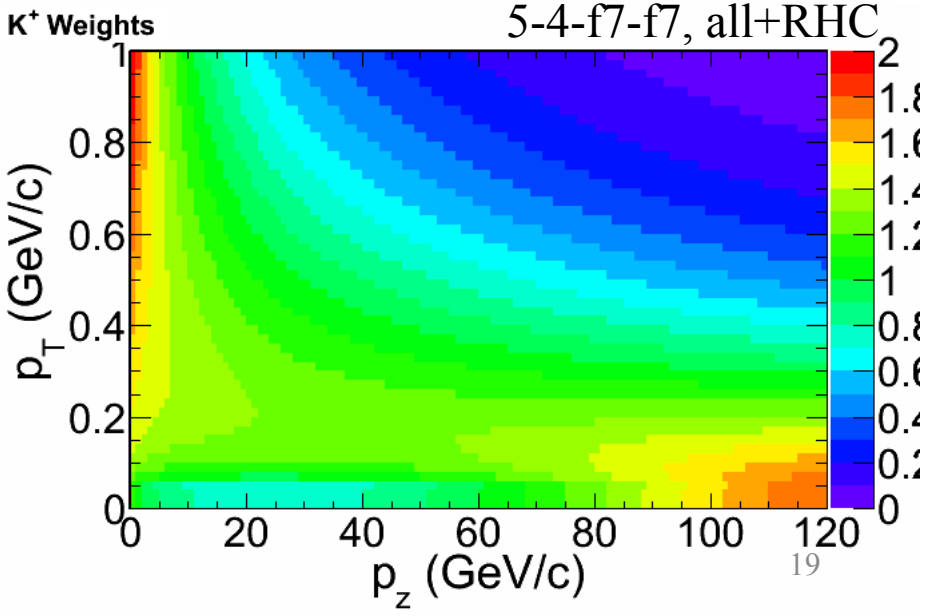

π⁻ Weights
5-4-f7-f7, all+RHC
p_T (GeV/c)
p_z (GeV/c)

# $K^+$ weights

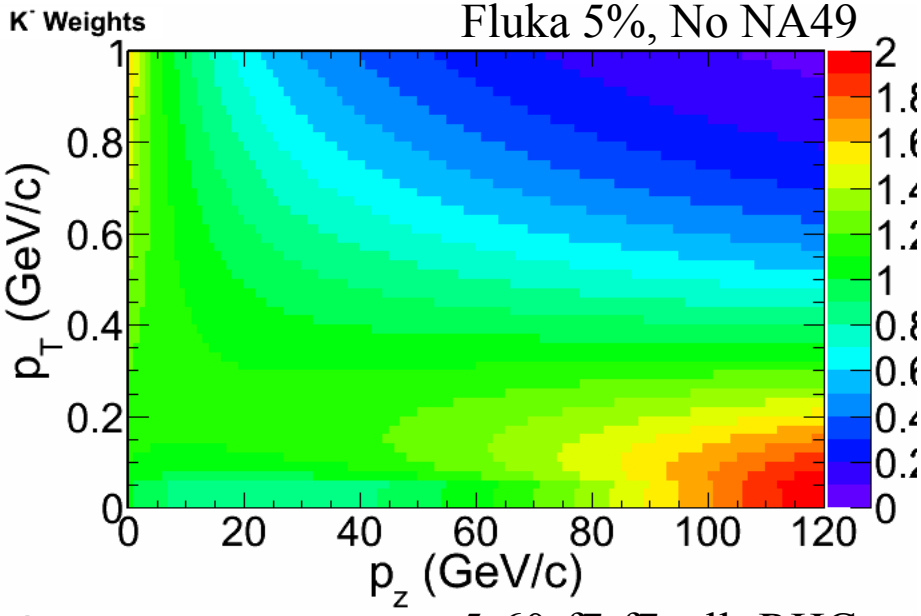

K⁺ Weights
Fluka 5%, No NA49
p_T (GeV/c)
p_z (GeV/c)

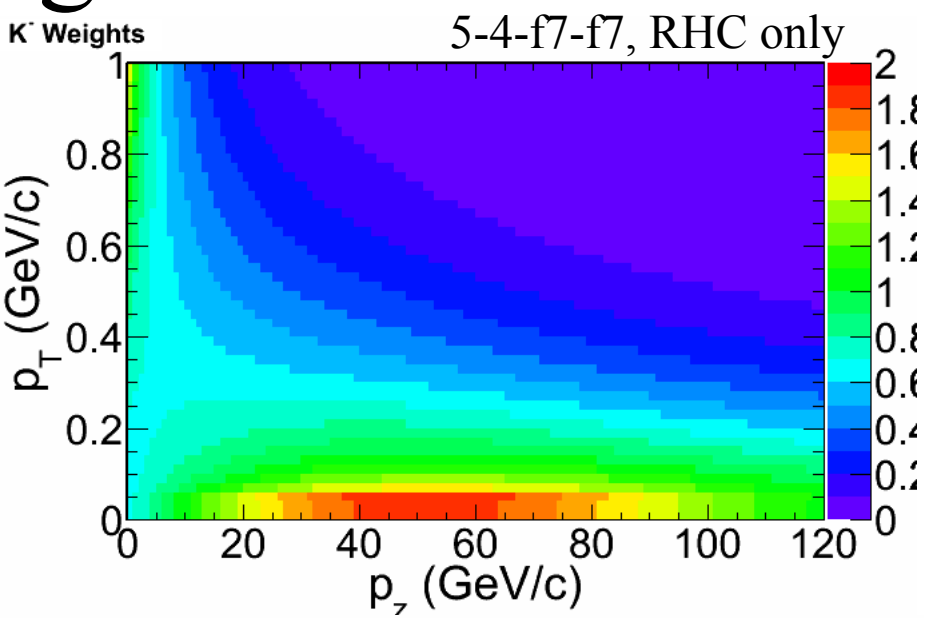

K⁺ Weights
5-4-f7-f7, RHC only
p_T (GeV/c)
p_z (GeV/c)

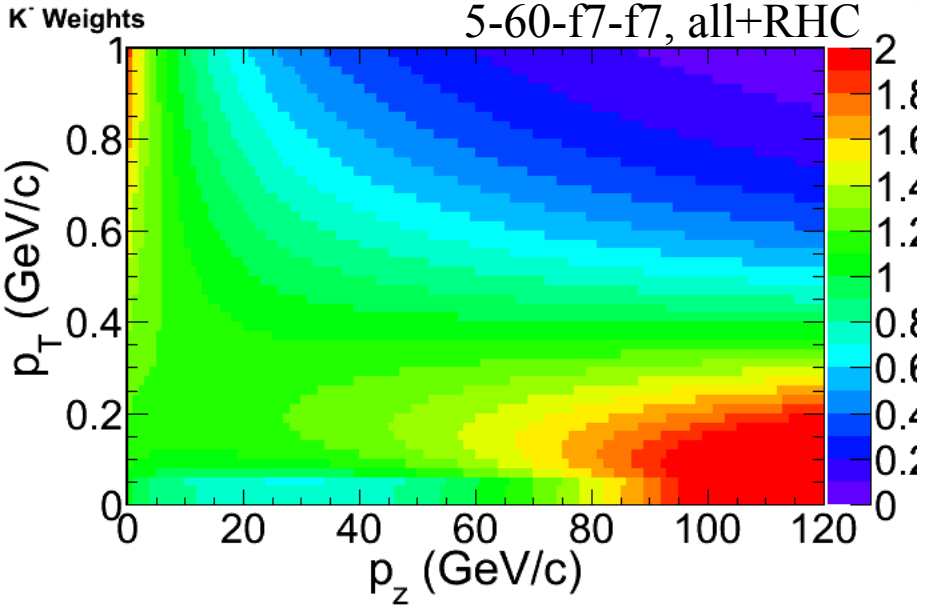

K⁺ Weights
5-60-f7-f7, all+RHC
p_T (GeV/c)
p_z (GeV/c)

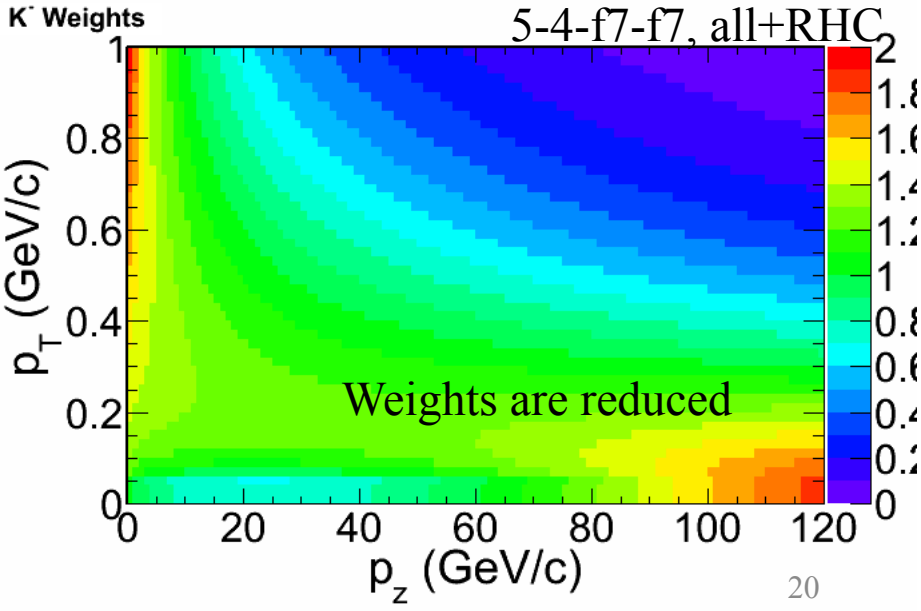

K⁺ Weights
5-4-f7-f7, all+RHC
p_T (GeV/c)
p_z (GeV/c)

# $K^-$ weights


K⁻ Weights
Fluka 5%, No NA49
p_T (GeV/c)
p_z (GeV/c)


K⁻ Weights
5-4-f7-f7, RHC only
p_T (GeV/c)
p_z (GeV/c)

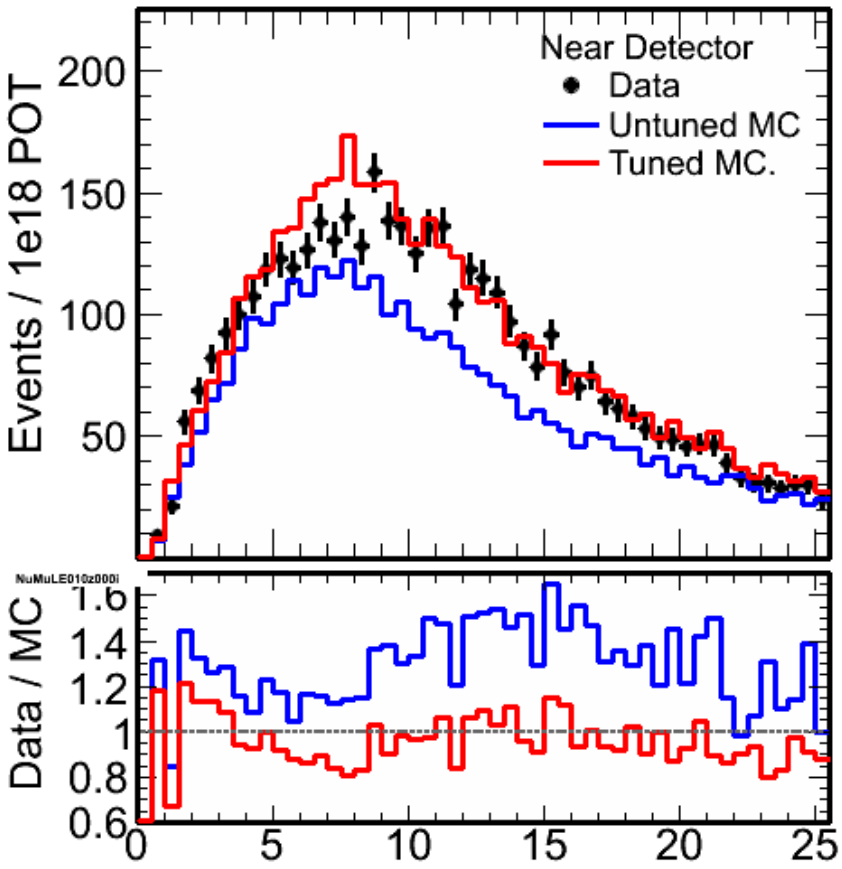

K⁻ Weights
5-60-f7-f7, all+RHC
p_T (GeV/c)
p_z (GeV/c)


K⁻ Weights
5-4-f7-f7, all+RHC
Weights are reduced
p_T (GeV/c)
p_z (GeV/c)

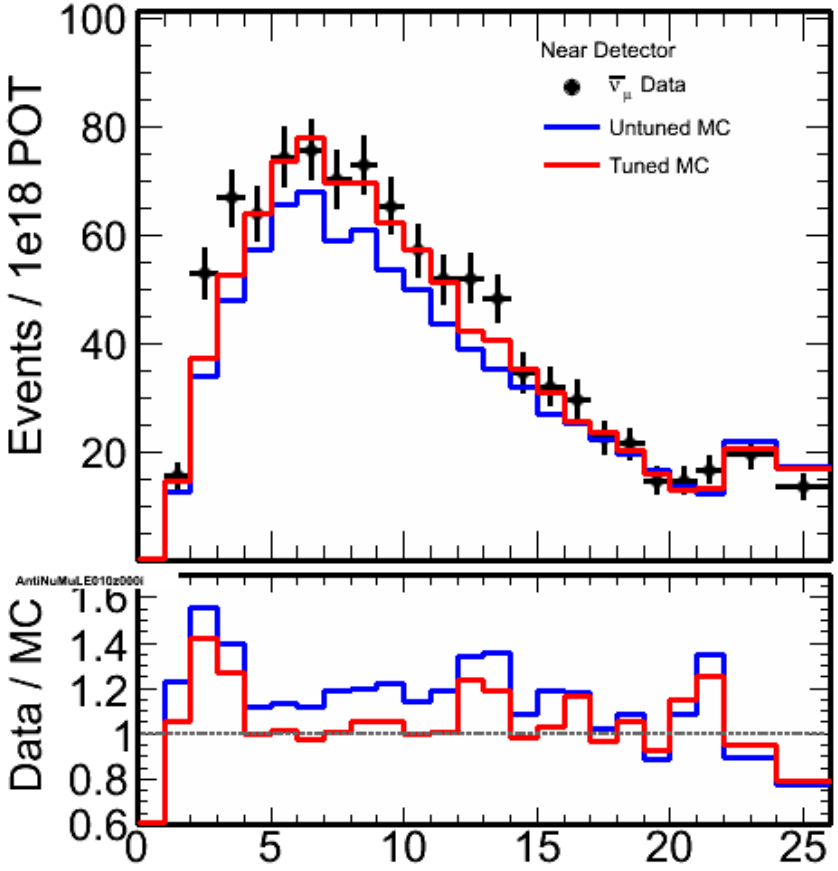
# Beam ratios

# L010z000 run1

**NuMu**

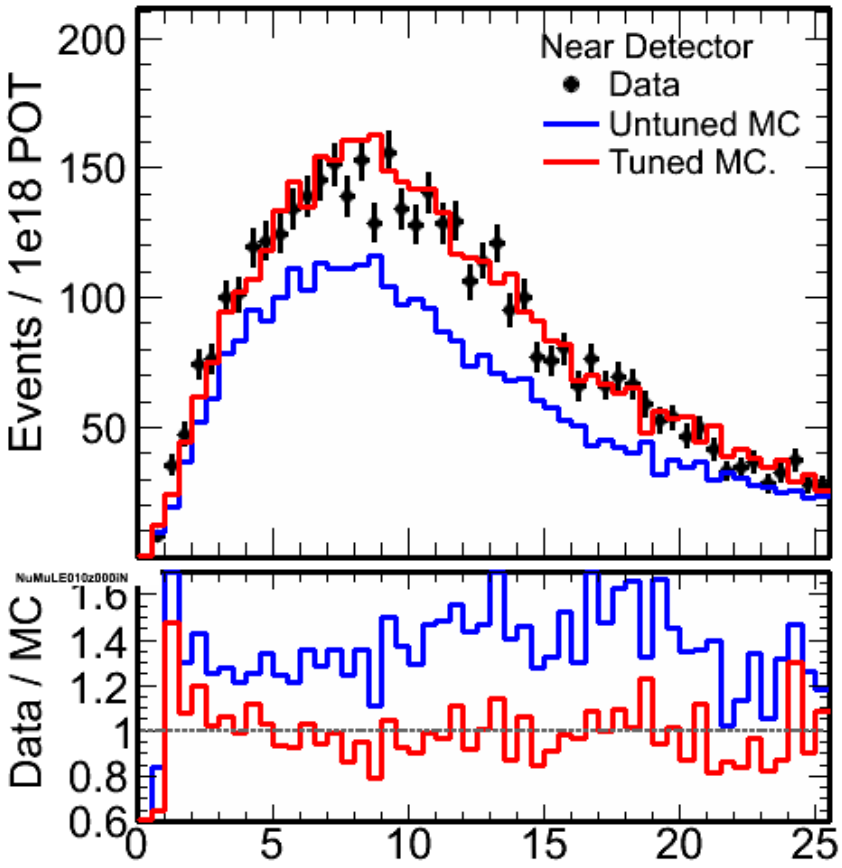



**NuMuBars**

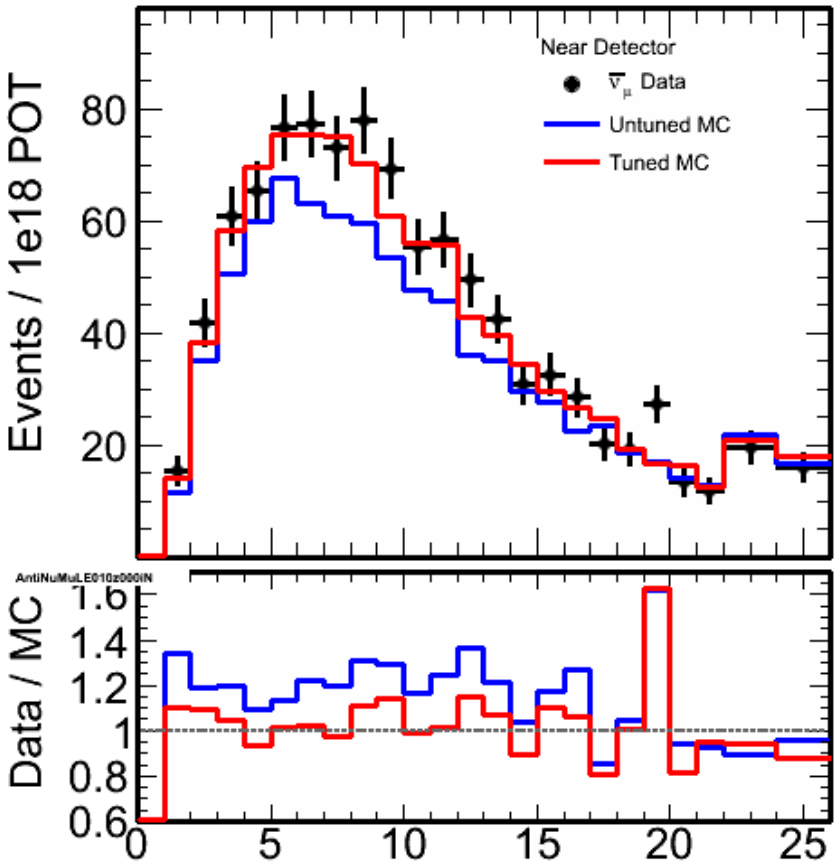


# L010z000 run2

**NuMu**

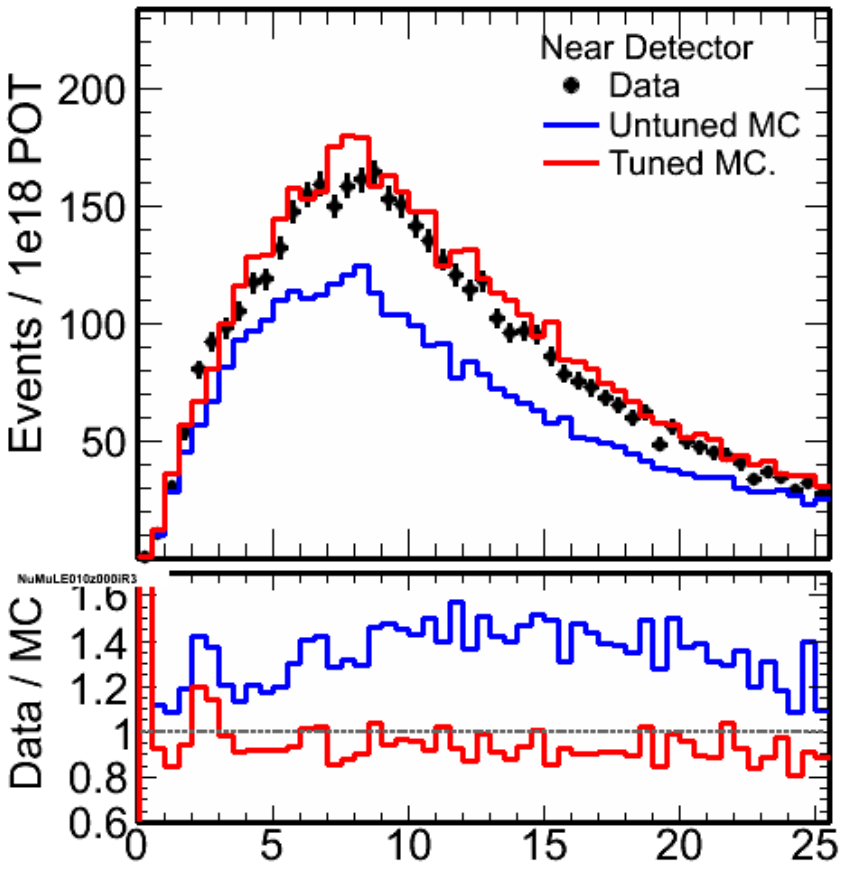



**NuMuBars**

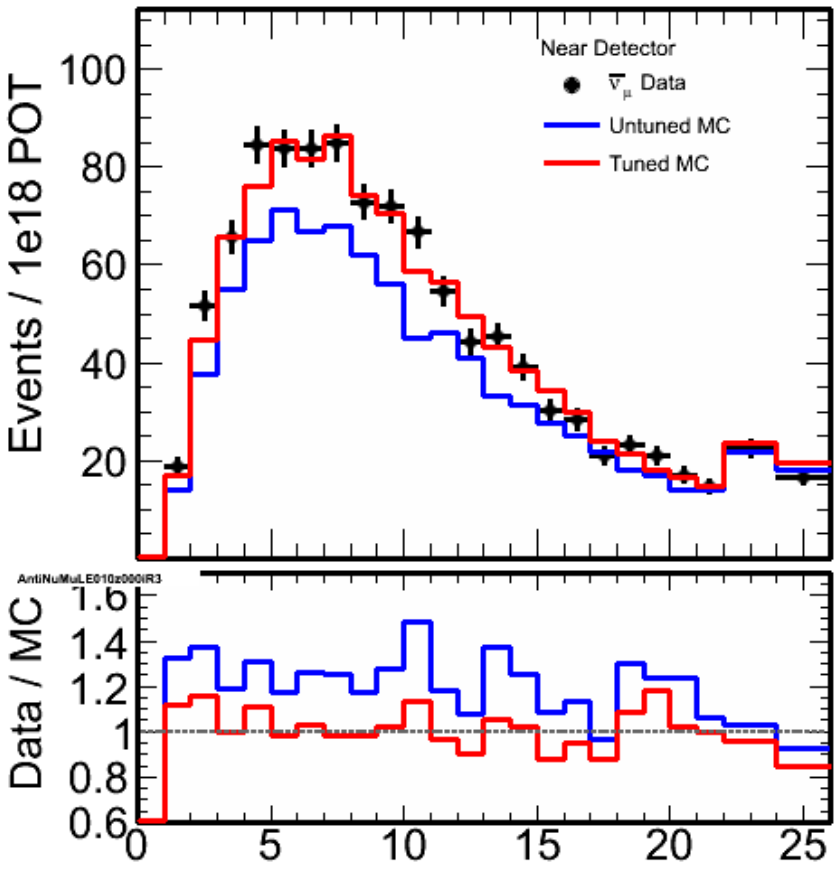


# L010z000 run3

**NuMu**

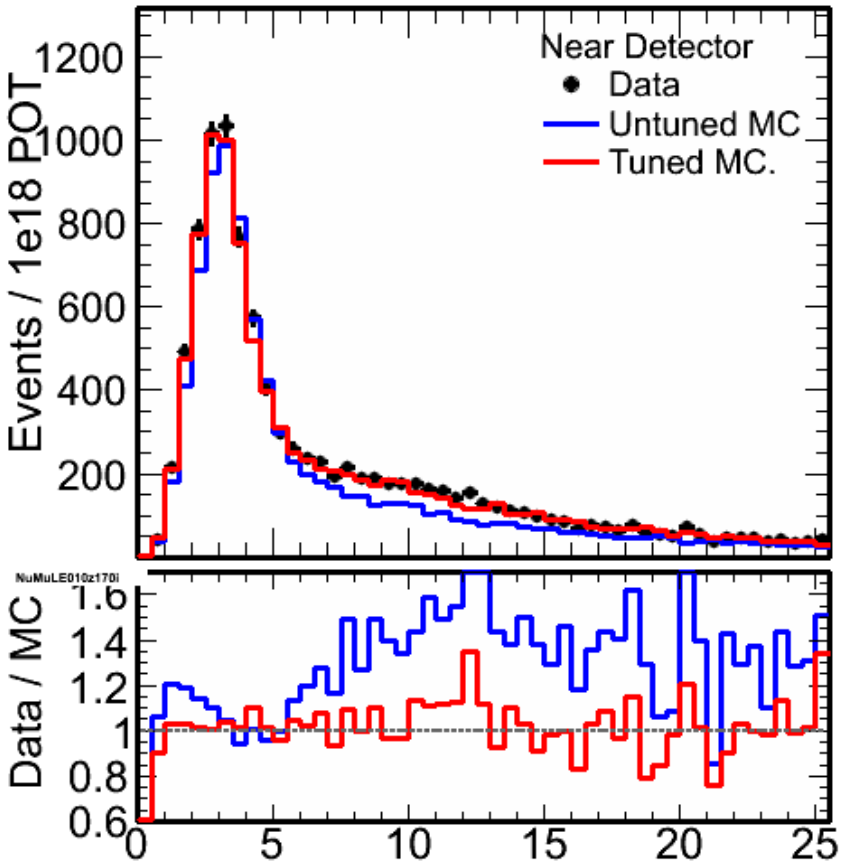



**NuMuBars**

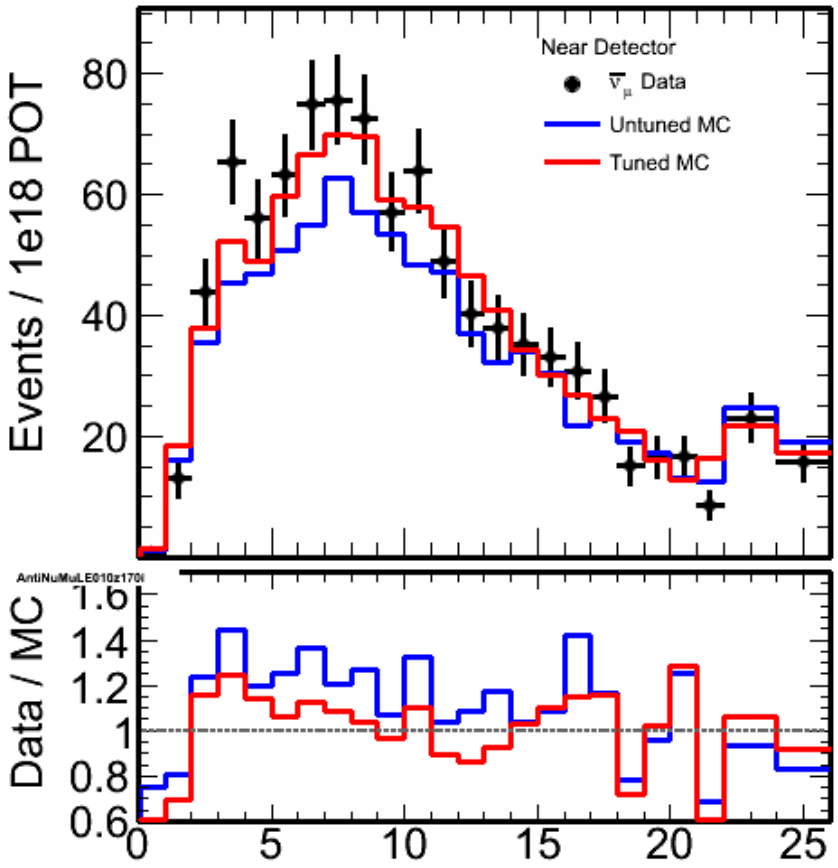


# L010z170 run1

**NuMu**

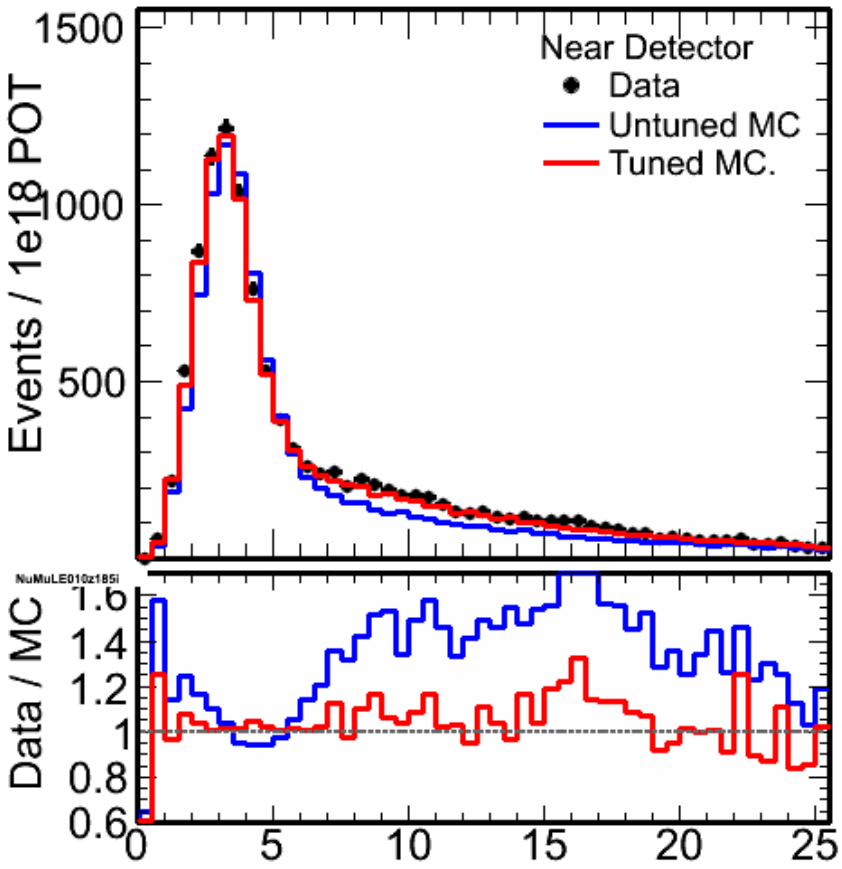



**NuMuBars**

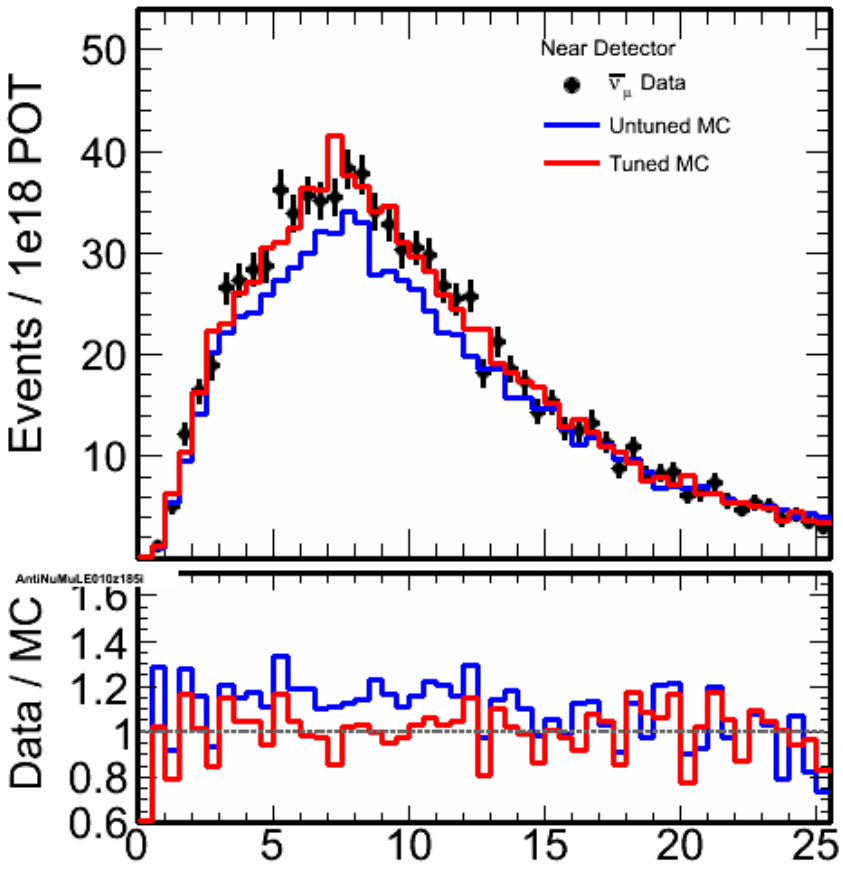


# L010z185 run1

**NuMu**

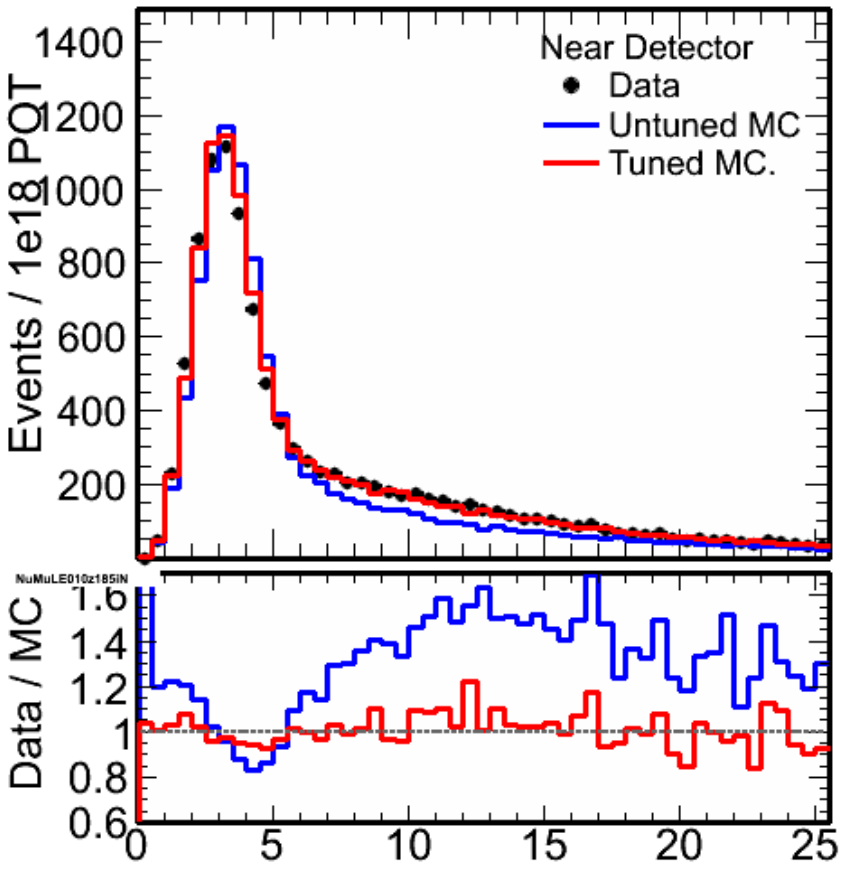



**NuMuBars**

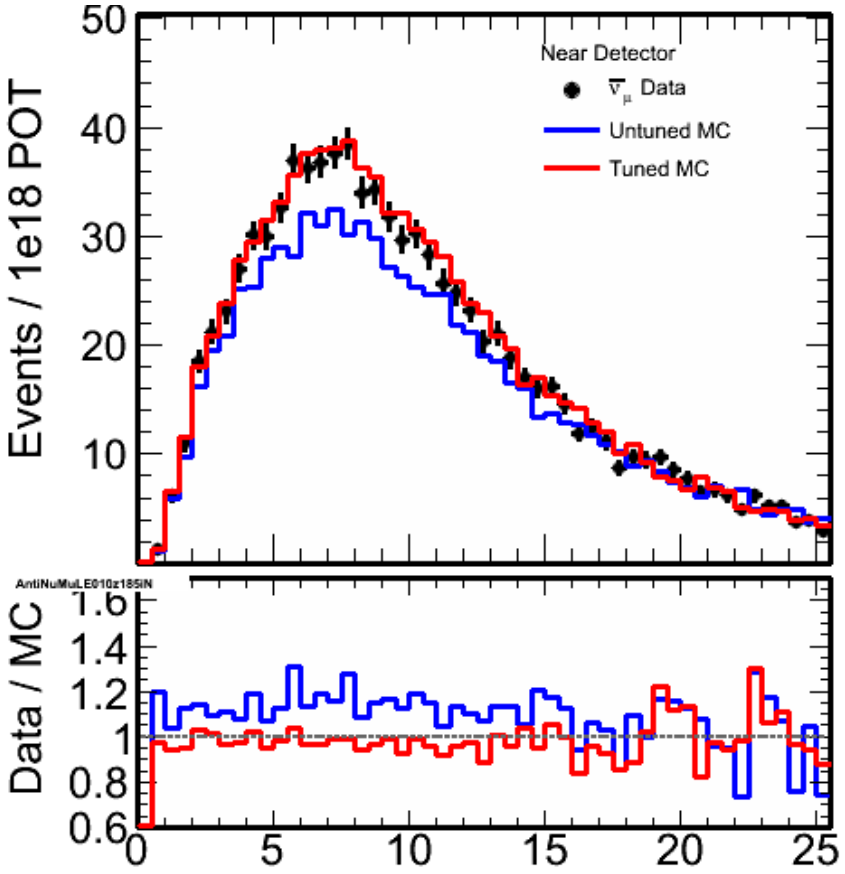


# L010z185 run3

**NuMu**

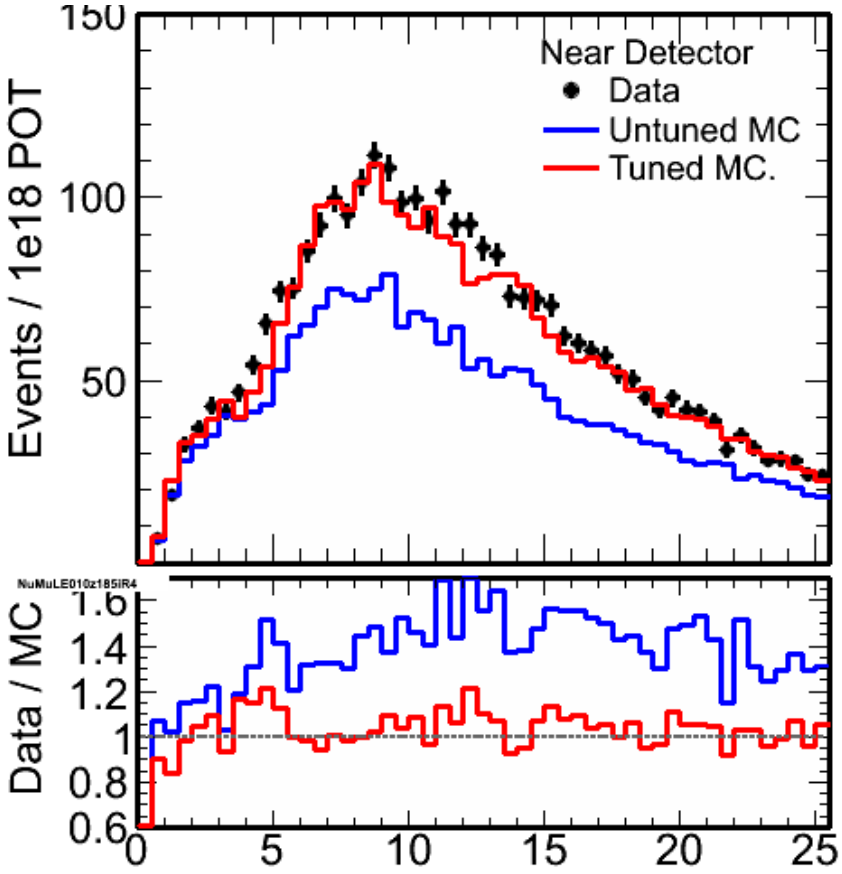



**NuMuBars**

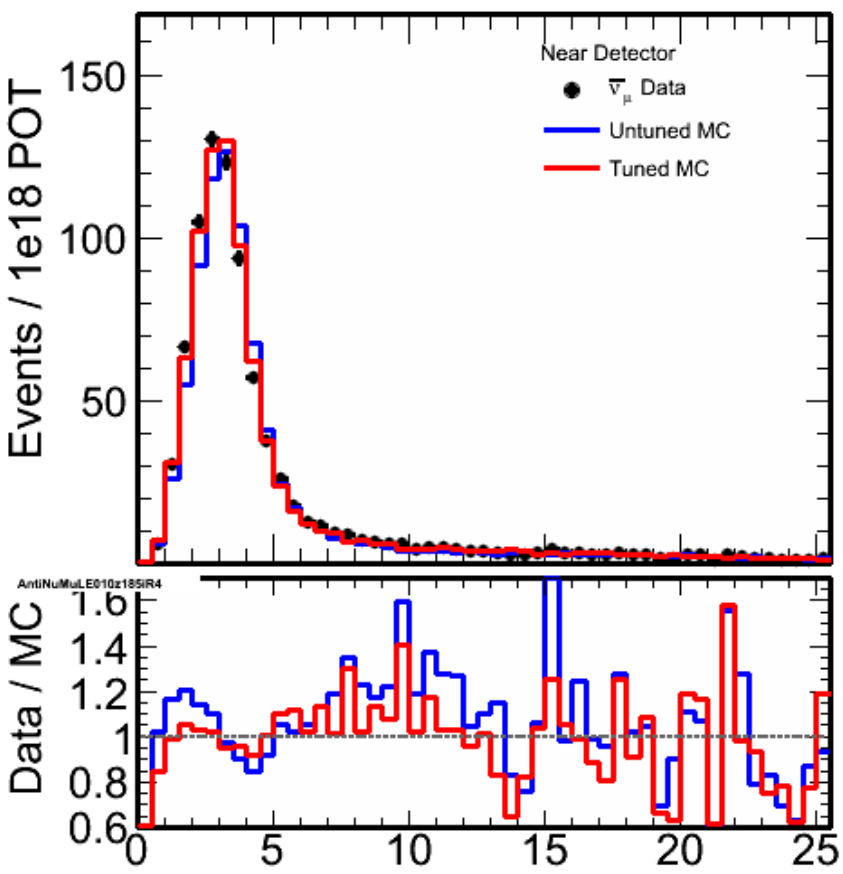


# L010z185 run4

**NuMu**

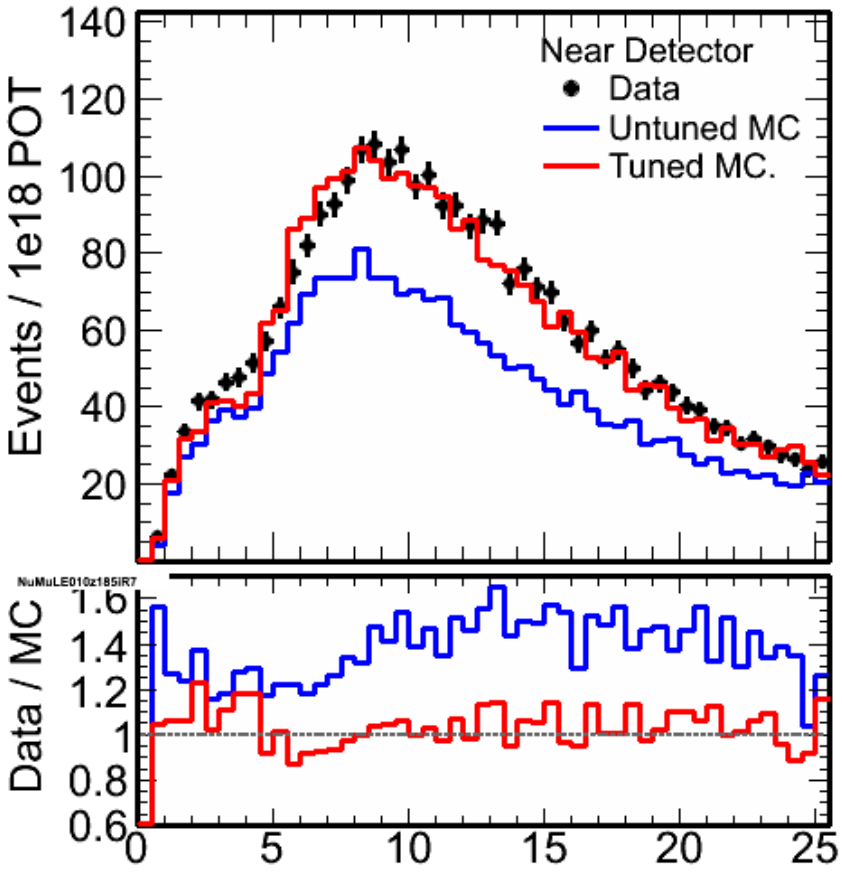



**NuMuBars**

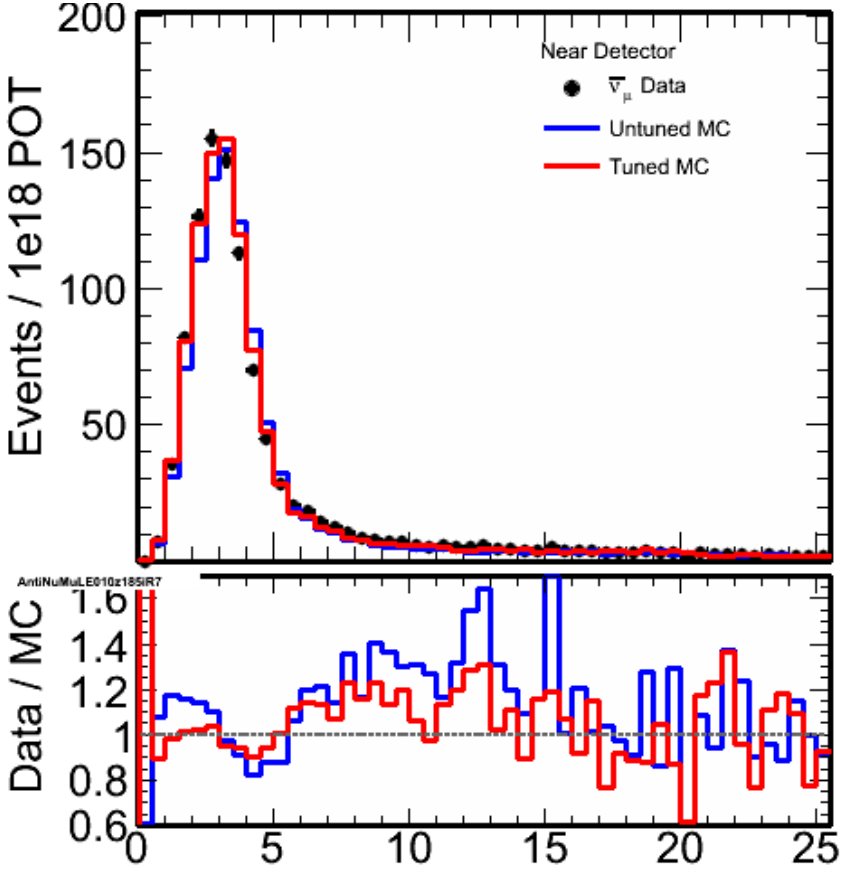


# L010z185 run7

**NuMu**

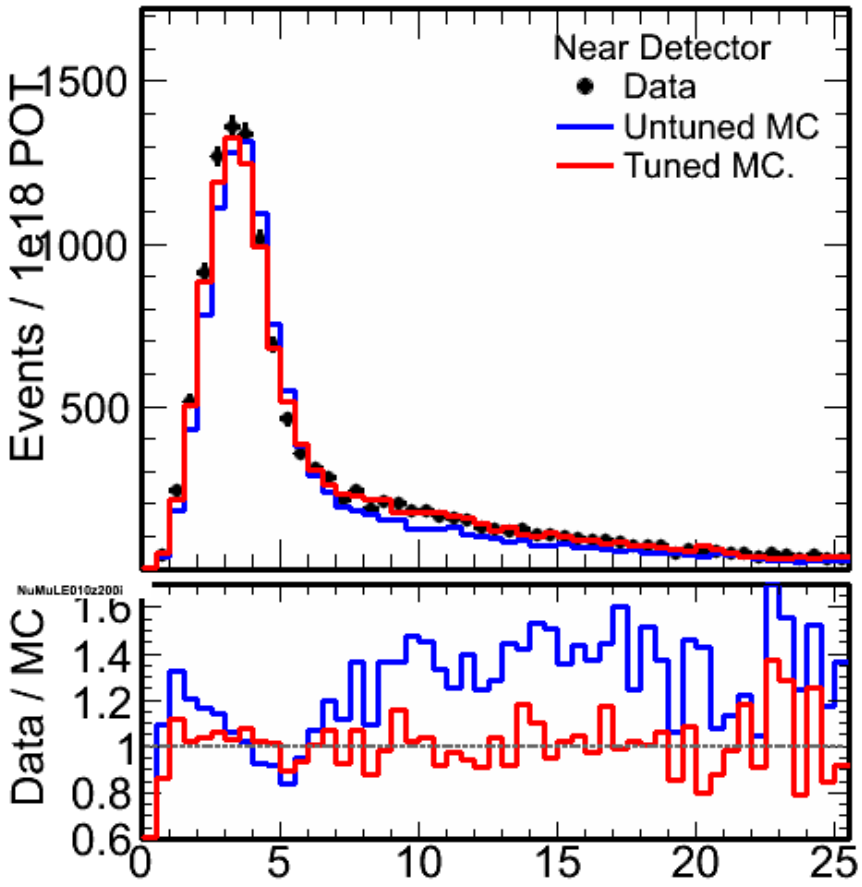



**NuMuBars**

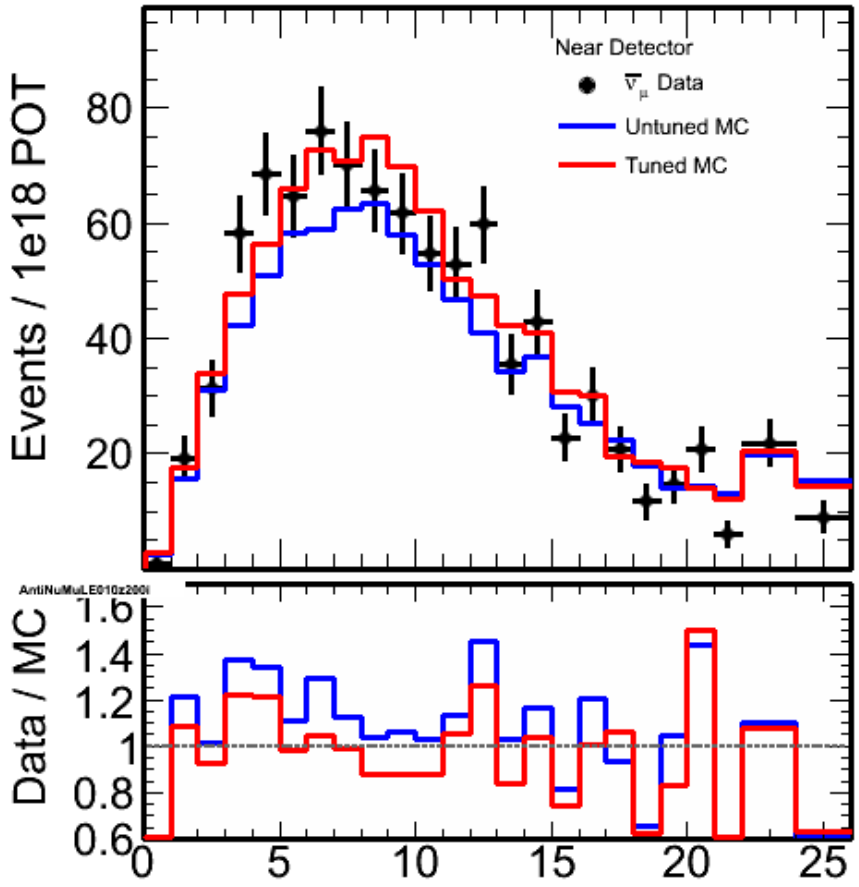


# L010z200 run1

**NuMu**

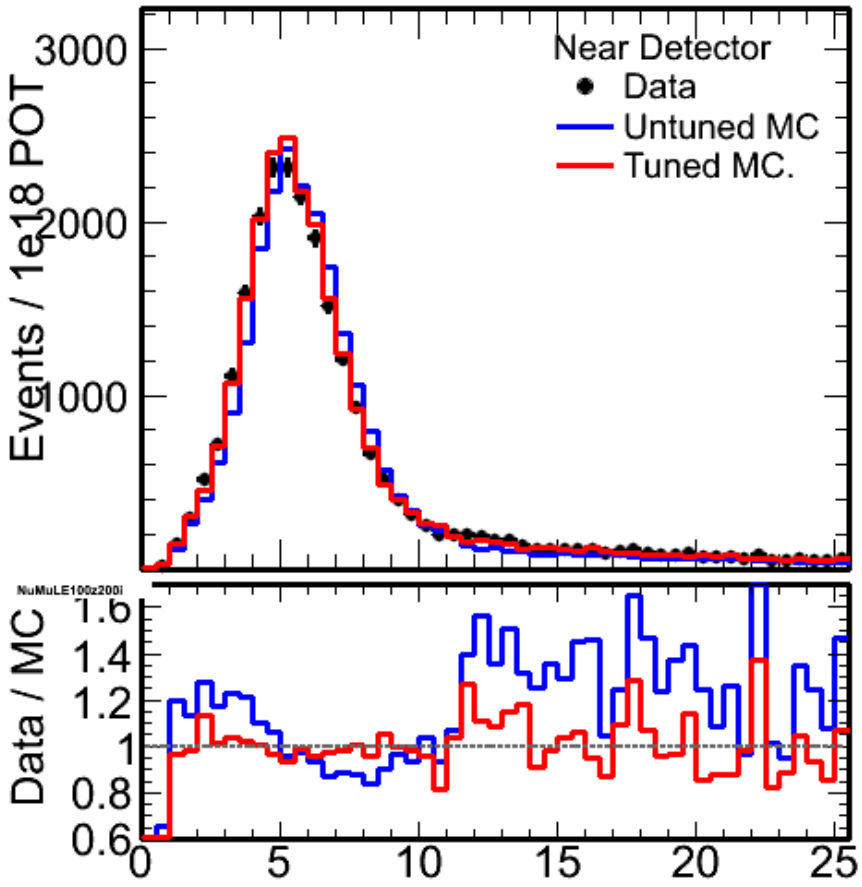



**NuMuBars**

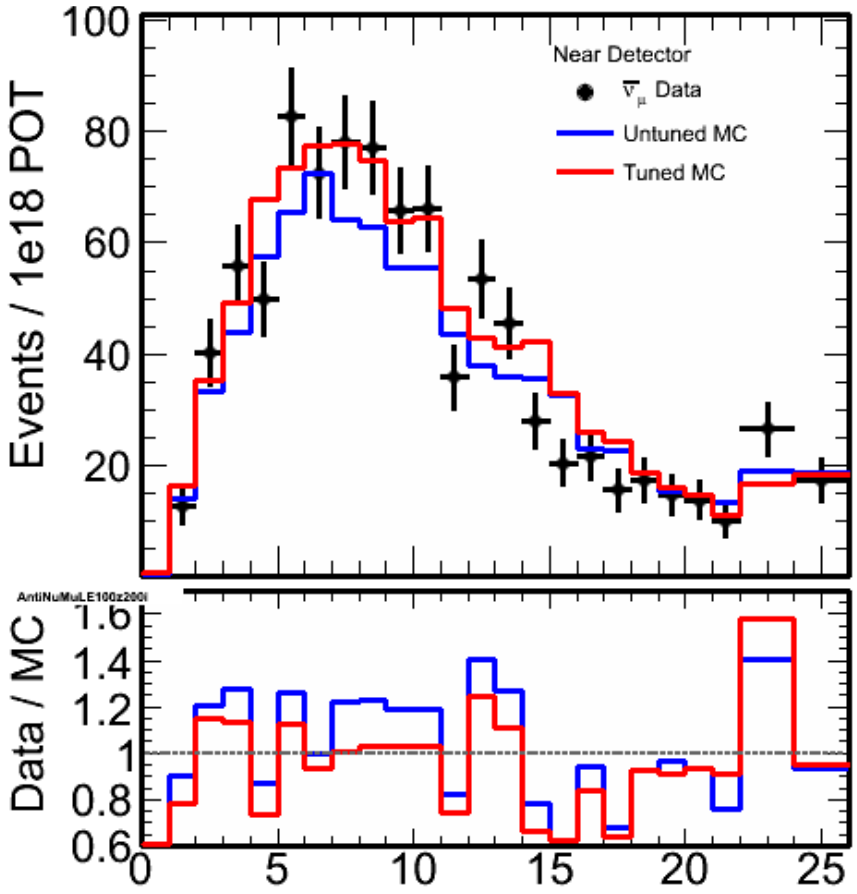


# L100z200 run1

**NuMu**

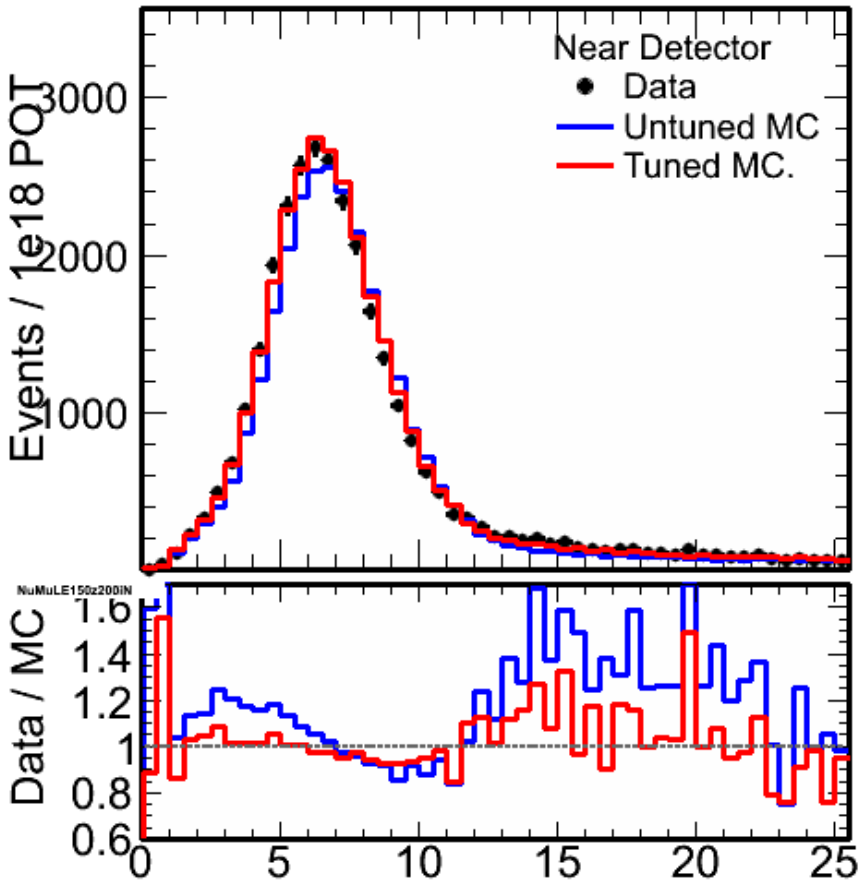



**NuMuBars**

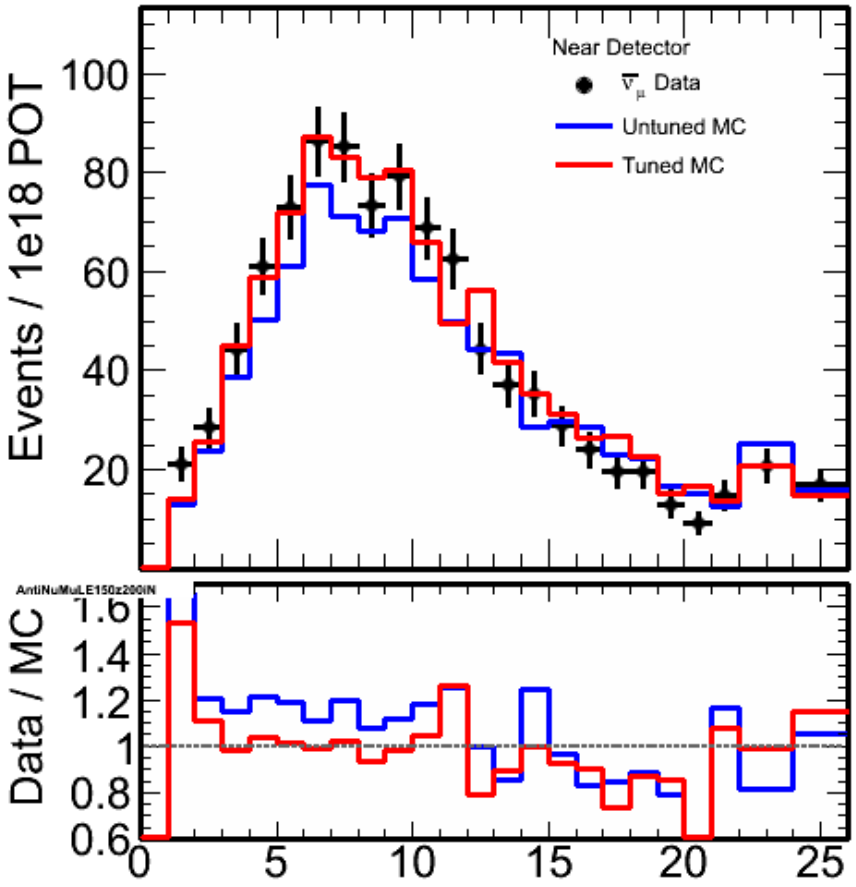


# L150z200 run2

**NuMu**

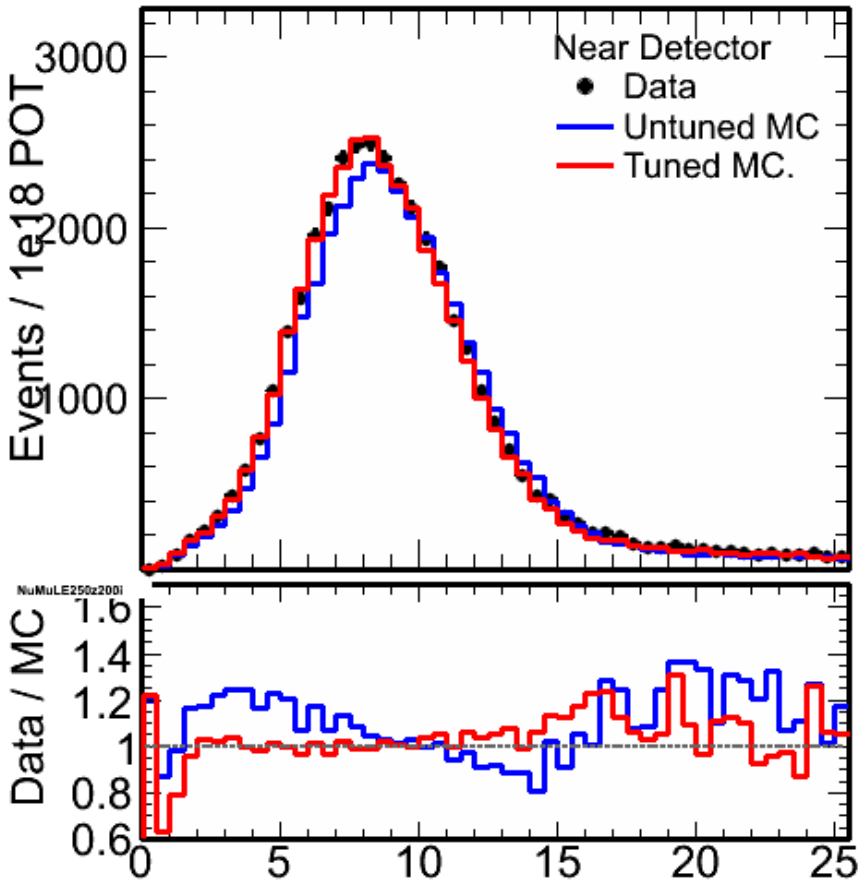



**NuMuBars**

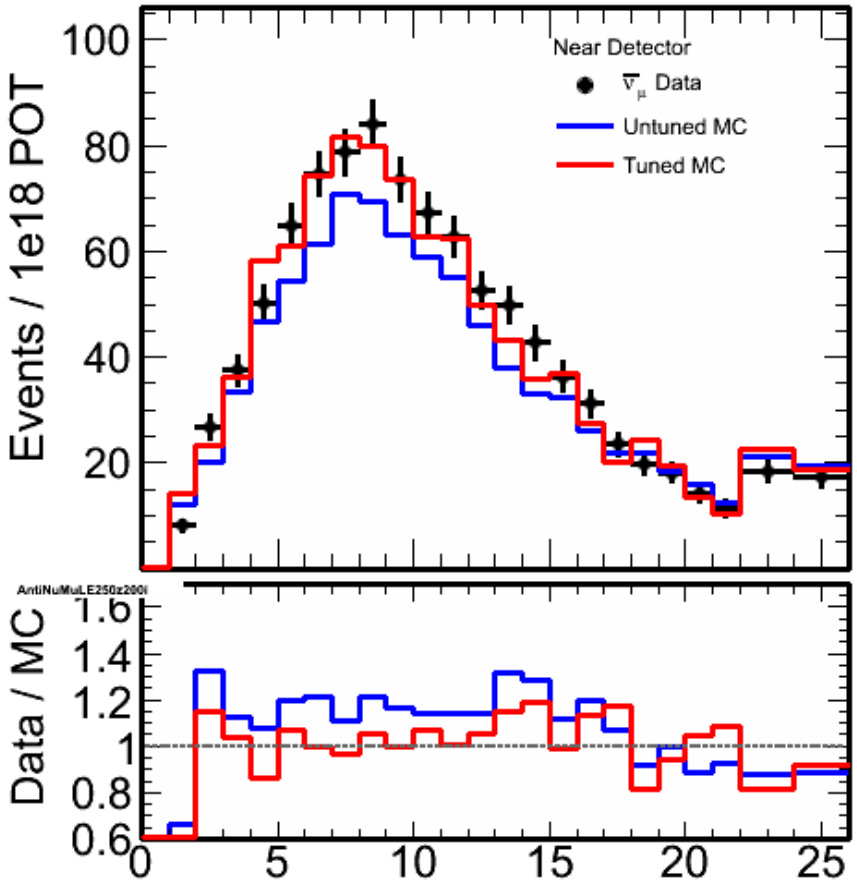


# L250z200 run1

**NuMu**




**NuMuBars**



# Fit parameters

# Focusing, decay and detector

Position paper, March 2010

| Fit Parameter | Nominal Value | Assumed 1σ | Best Fit Value | Error |
|---|---|---|---|---|
| Horn I mis-calibration (σ) | 0.00 | Free | -3.85 | 0.44 |
| Horn I distribution (σ) | 0.00 | Free | 1.39 | 0.58 |
| Target decay Run 2 (2 fins) | 0.00 | 1.00 | 0.83 | 0.23 |
| Target decay Run 3 (2 fins) | 0.00 | 2.00 | 2.81 | 0.22 |
| Neutrino energy scale (%) | 0.00 | 5.00 | -1.94 | 0.15 |
| $\bar{\nu}_\mu$ cross section | 1.00 | 0.30 | 1.05 | 0.03 |
| NC normalization $\nu_\mu$-CC (%) | 0.00 | 30.0 | 38.2 | 16.6 |
| NC normalization $\bar{\nu}_\mu$-CC (%) | 0.00 | 30.0 | -25.1 | 27.4 |

RHC only

| | | |
|---|---|---|
| Horn I_mis-calib | 9.19 | 2.98 |
| Horn I_distribution | -5.70 | 1.35 |
| Target decay Run 2 | 0.83 | fixed |
| Target decay Run 3 | 2.81 | fixed |
| Nue energy scale (%) | -3.71 | 0.51 |
| Nubar cross-section | 1.48 | 0.25 |
| NC norm numu (%) | 47.4 | 25.0 |
| NC norm nubar (%) | -28.7 | 32.0 |

all + RHC

| | | |
|---|---|---|
| Horn I_mis-calib | -2.99 | 0.35 |
| Horn I_distribution | 1.30 | 0.42 |
| Target decay Run 2 | 0.83 | fixed |
| Target decay Run 3 | 2.81 | fixed |
| Nue energy scale (%) | -2.90 | 0.11 |
| Nubar cross-section | 1.03 | 0.02 |
| NC norm numu (%) | 43.2 | 13.6 |
| NC norm nubar (%) | 6.7 | 17.8 |

Within errors of the fits, all+RHC case is quite (mostly) close to the Pos.paper (no RHC was available at that time). NC norm errors are quite big, and should not be of concern.

# Hadron production parameters

Position paper

| Fit Parameter | Best Fit Value | Error | Fit Parameter | Best Fit Value | Error |
|---|---|---|---|---|---|
| $\pi^+$ Par 0 | 1.56 | 0.14 | $K^+$ Par 0 | 3.50 | 1.00 |
| $\pi^+$ Par 1 | -6.42 | 0.68 | $K^+$ Par 1 | 4.83 | 3.43 |
| $\pi^+$ Par 2 | 1.11 | 0.02 | $K^+$ Par 2 | 1.51 | 0.08 |
| $\pi^+$ Par 3 | 0.13 | 0.10 | $K^+$ Par 3 | 0.29 | 0.16 |
| $\pi^+$ Par 4 | 1.00 | 0.02 | $K^+$ Par 4 | 0.97 | 0.04 |
| $\pi^+$ Par 5 | 1.25 | 0.14 | $K^+$ Par 5 | 2.16 | 0.21 |
| $\pi^-$ Par 0 | 1.04 | 0.02 | $K^-$ Par 0 | 0.88 | 0.05 |
| $\pi^-$ Par 1 | -0.89 | 0.05 | $K^-$ Par 1 | 0.05 | 0.01 |

RHC only

| | | | | | |
|---|---|---|---|---|---|
| pi+_par 0 | -0.49 | 0.26 | k+_par 0 | 0.42 | 1.79 |
| pi+_par 1 | -3.56 | 2.29 | k+_par 1 | -16.9 | 7.25 |
| pi+_par 2 | 0.58 | 0.11 | k+_par 2 | 0.62 | 0.12 |
| pi+_par 3 | 1.46 | 0.70 | k+_par 3 | 0.90 | 0.46 |
| pi+_par 4 | 0.84 | 0.11 | k+_par 4 | 0.82 | 0.10 |
| pi+_par 5 | 3.63 | 0.96 | k+_par 5 | 3.96 | 1.08 |
| pi-_par 0 | 1.08 | 0.03 | k-_par 0 | 0.99 | 0.03 |
| pi-_par 1 | -0.89 | 0.08 | k-_par 1 | -0.21 | 0.20 |

all+ RHC

| | | | | | |
|---|---|---|---|---|---|
| pi+_par 0 | 1.76 | 0.08 | k+_par 0 | 4.16 | 1.03 |
| pi+_par 1 | -9.91 | 0.41 | k+_par 1 | 6.33 | 3.14 |
| pi+_par 2 | 1.10 | 0.01 | k+_par 2 | 1.53 | 0.07 |
| pi+_par 3 | -0.35 | 0.06 | k+_par 3 | 0.34 | 0.14 |
| pi+_par 4 | 1.06 | 0.02 | k+_par 4 | 0.94 | 0.04 |
| pi+_par 5 | 0.18 | 0.11 | k+_par 5 | 2.01 | 0.20 |
| pi-_par 0 | 1.03 | 0.02 | k-_par 0 | 0.95 | 0.02 |
| pi-_par 1 | -0.84 | 0.04 | k-_par 1 | 0.07 | 0.11 |

# Summary

- New fit with DSTs looks fine to me. Some of the beam ratio plots look better then it was with PANS.
- I don't think that selection of data/MC need to be changed. Certainly not for NuMuBars.
- Things still to do: use corrected Run I-III MC microDST (should be available this week).
- I am still not happy with the special 2010 runs, I expect new data and MC summary files obtained with R2.7. (MC Runs I-III FHC were done by Joe yesterday!).
- Things look good and I expect to converge with the fit parameters as early as next week, however, these new fit values could be tested with GetSKZPWeightCalculatorCustom function quite easily (Anna ?).