Detector Systematic Studies for fiTQun ATMPD Analyses - Status and Plans -

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(Most plots are made by ↑!)

fiTQun! Workshop
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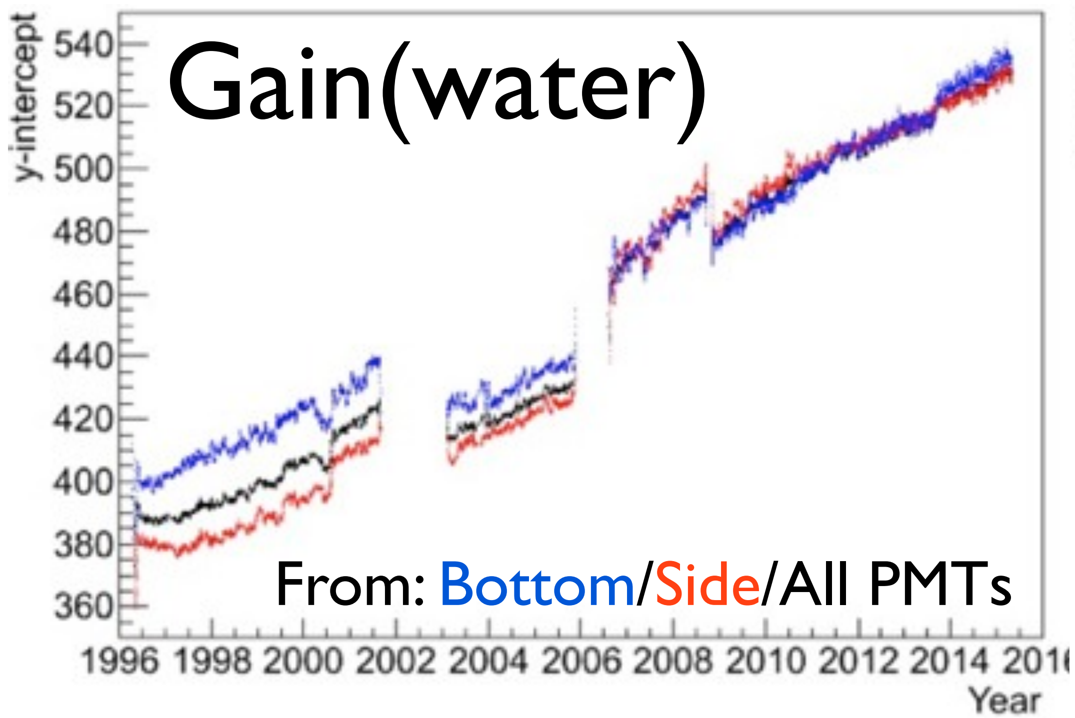
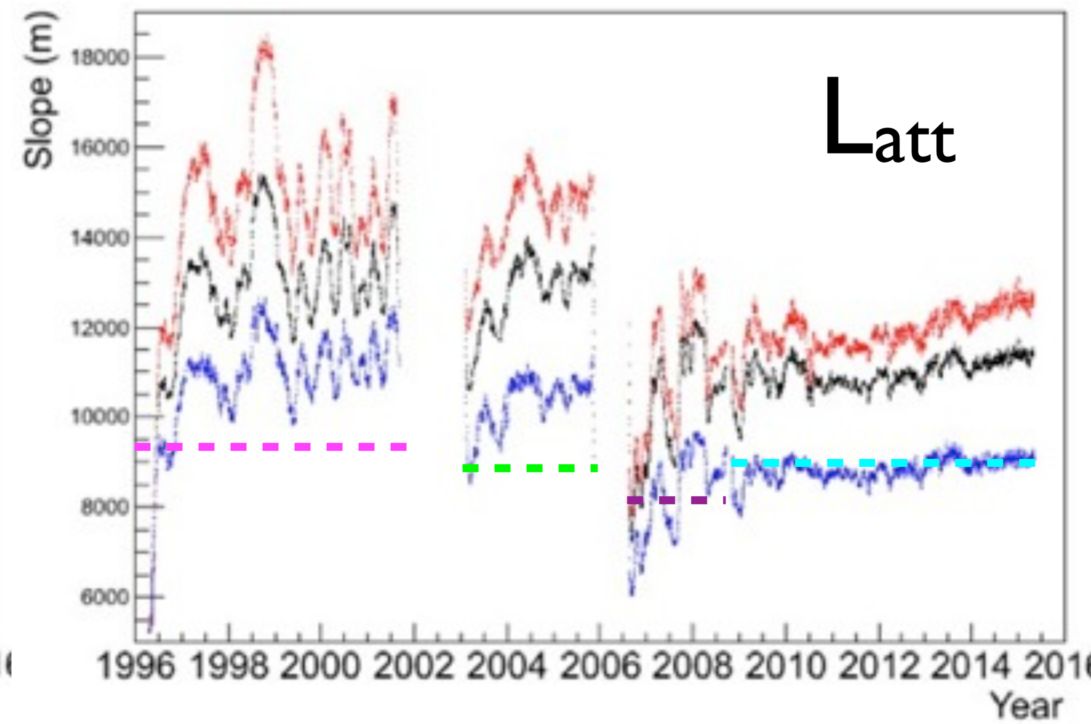
Please also see: http://www-sk.icrr.u-tokyo.ac.jp/indico/materialDisplay.py?contribId=53&sessionId=3&materialId=slides&confId=2145

Overview

- Since v4r2, we can run fiTQun on SK1-3
- In order to do full fiTQun ATMPD analyses, we have been studying data/MC samples from all SK1-4
  - Stopping-μ, decay-e, Atm-ν 2Rπ^0
- Lots of progress in understanding time-dependent effects
  - fiTQun-reconstructed variables have stabilized over time by introducing corrections for time varying detector constants in fiTQun
- Absolute agreement of data & MC is also studied
  - Larger discrepancy seen in SK1, 3?
  - Need to understand this!

Time Variations of Gain, L_{att}

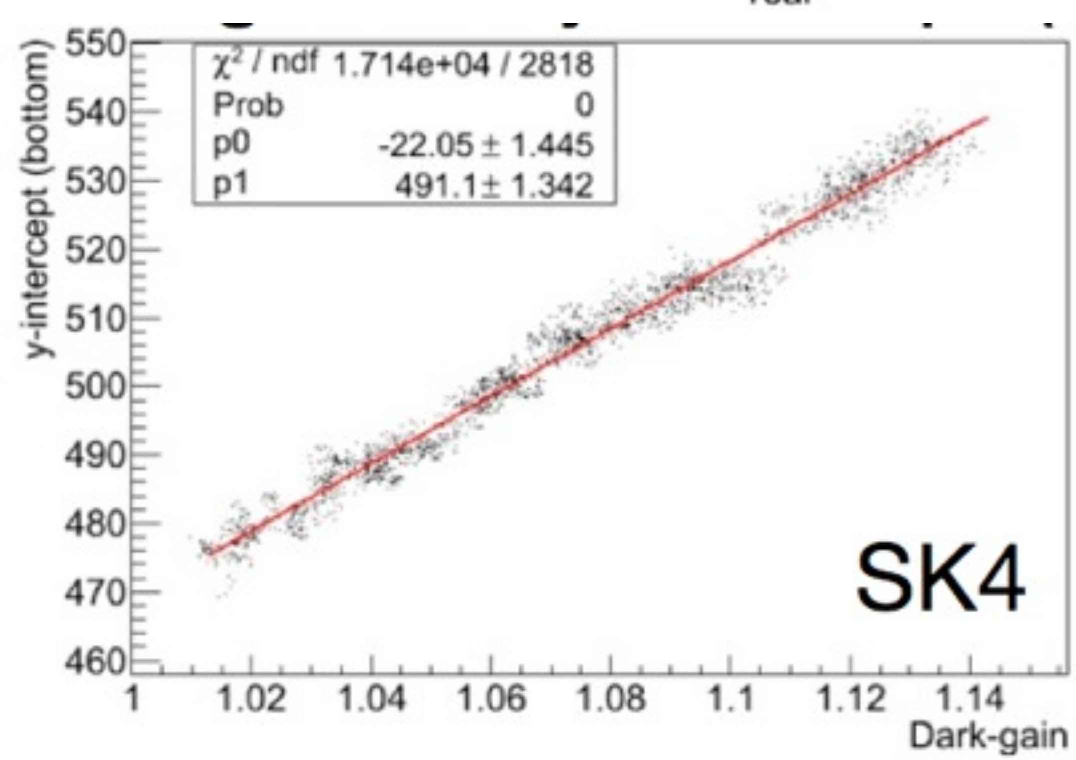




L_{att} for MC:
SK1: 9372.0m
SK2: 8841.5m
SK3: 8157.8m
SK4: 8960.0m

SK1,2 MC water can be tuned better?

- In SK1-4, time variations of gain and L_{att} are monitored using attenuation curve obtained from thru-mu events
  - Gain: y-intercept, L_{att}: slope
  - Values from bottom PMTs are used
- In SK4, gain is also monitored using 1p.e. peak - used in AP/fQ for gain correction
- Gain steadily increases over years
- L_{att} has short term variations, large variation in SK1, stable in SK4

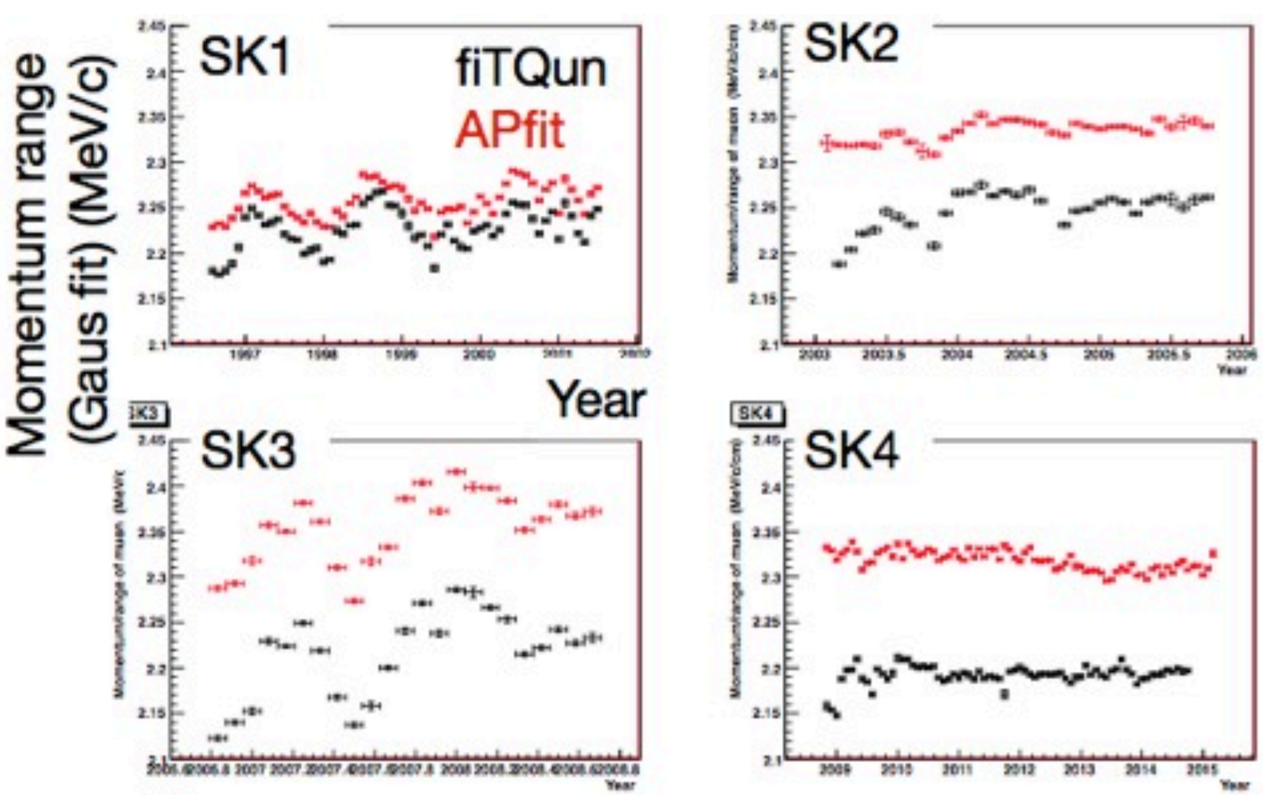


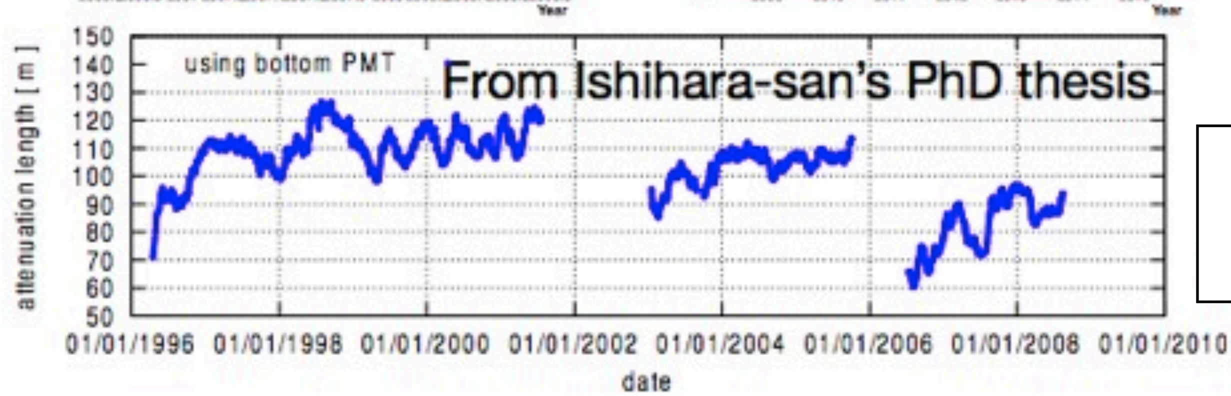
Gain obtained from attenuation curve has shorter-term fluctuations

Gain&L_{att} Corrections

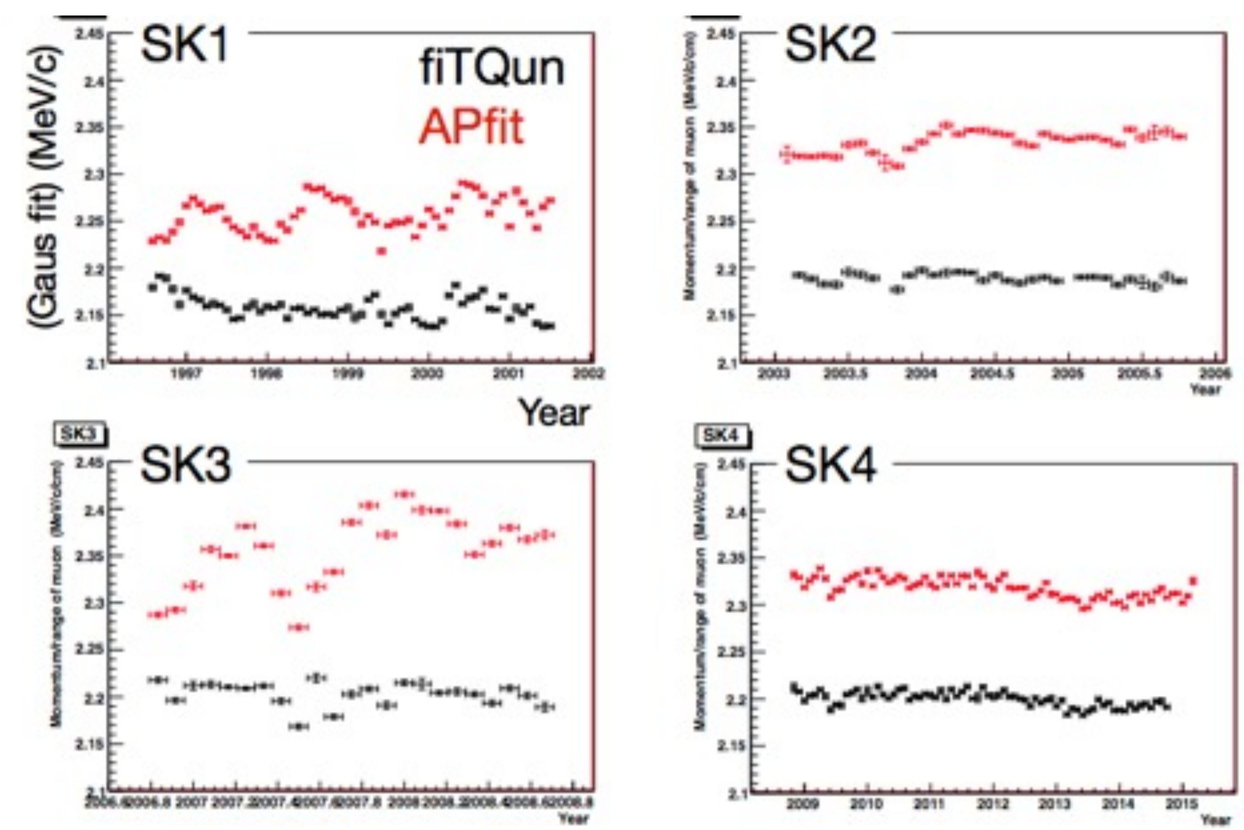
- When applied on data events, fiTQun now uses the run-by-run gain and attenuation length to suppress the time variation of reconstructed quantities

Gain corr. only





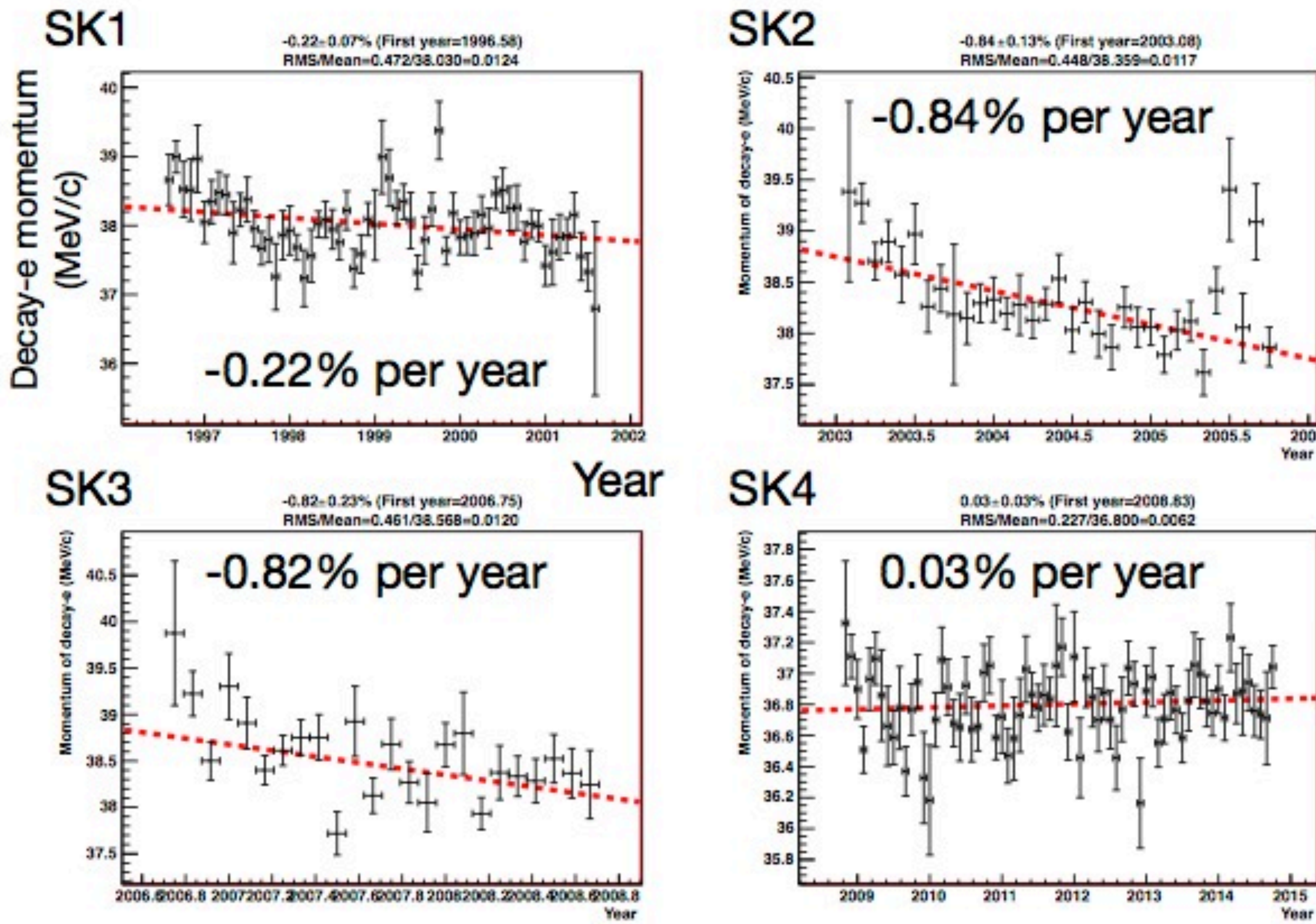
Gain & L_{att} corr.

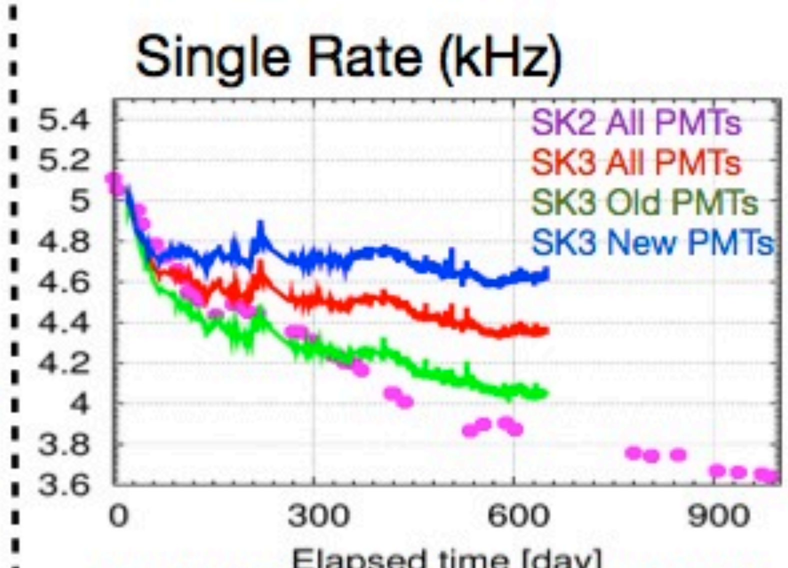


w/o L_{att} correction, clear correlation is seen between time variations of p/range and L_{att}

Decay-e Momentum t-variation

- We see some decrease in decay-e momentum over time in SK2&3
  - Don't see this in p/range of multi-GeV muons
- Probably caused by decrease in "dark hit" rate (actually by FRP)





A. Takeda@SK collab. in Apr. 2008

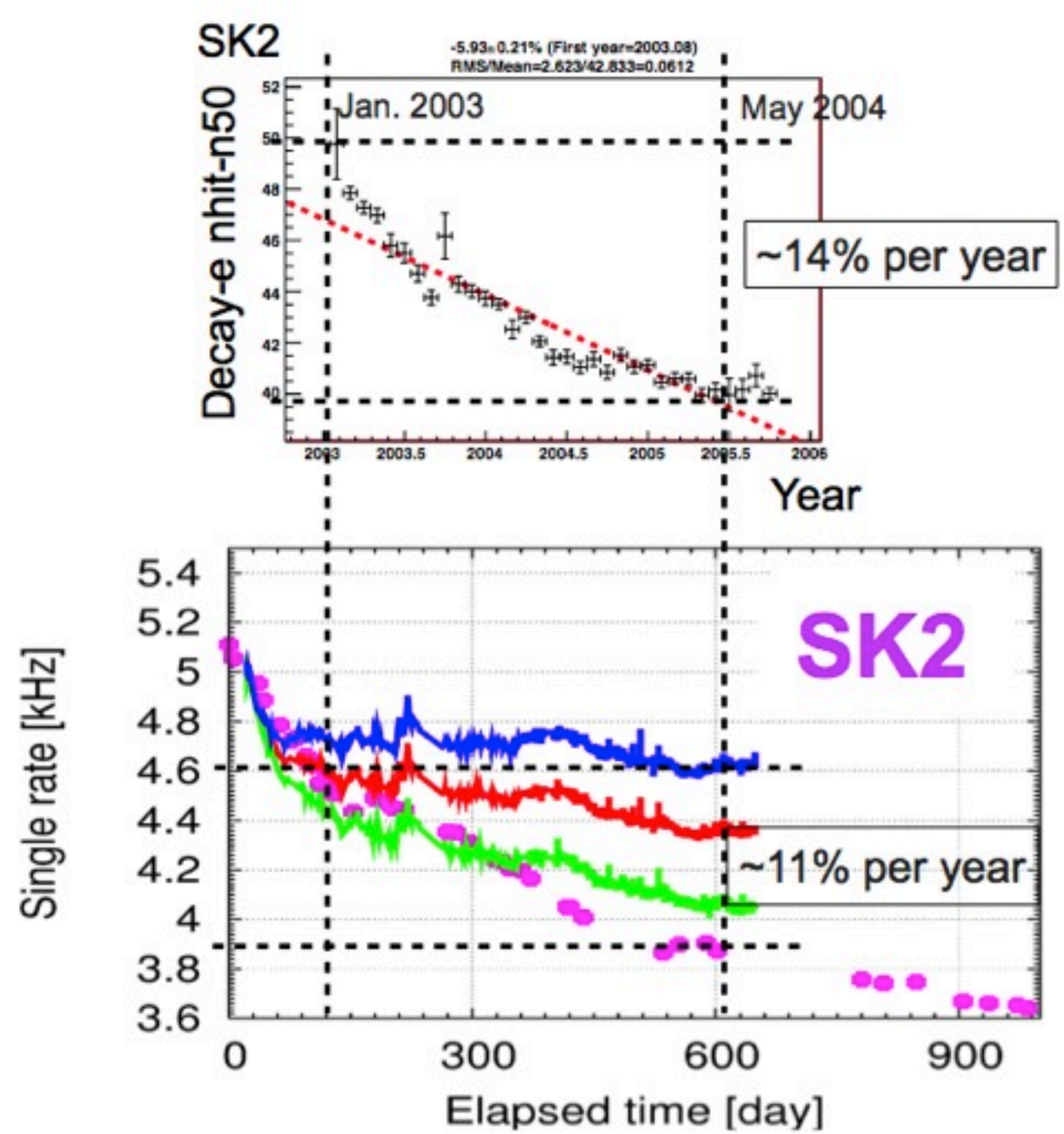
RMS/Mean (%)	SK1	SK2	SK3	SK4
fiTQun	**1.24**	**1.17**	**1.20**	**0.62**
APfit 14a	0.77	0.56	1.01	0.47

Post fQ v4r2 w/o decay-e improvement 8

Dark rate and off-timing hits

- When we look at time variations of off-timing hit rates in fiTQun time window, it seems to be correlated with the change in dark hit rates!

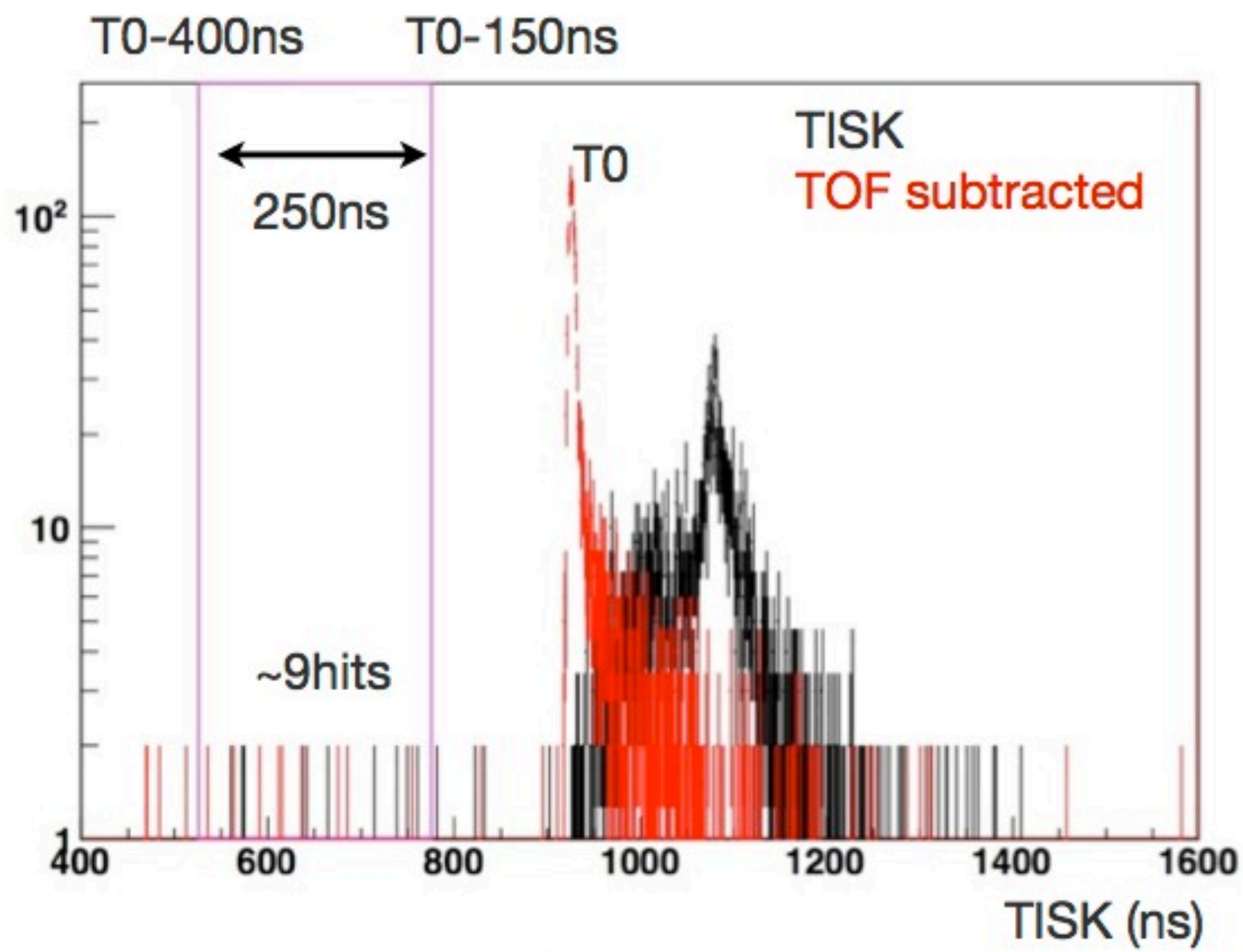
- fiTQun is affected more by such effect than APfit, as the time window is longer(~μs)



Measuring dark rate variations

- We can use the early off-timing hit rates before hi-E triggers to monitor the change in dark rates

- APfit looks at hit rates in early 250ns window on event-by-event basis and apply correction



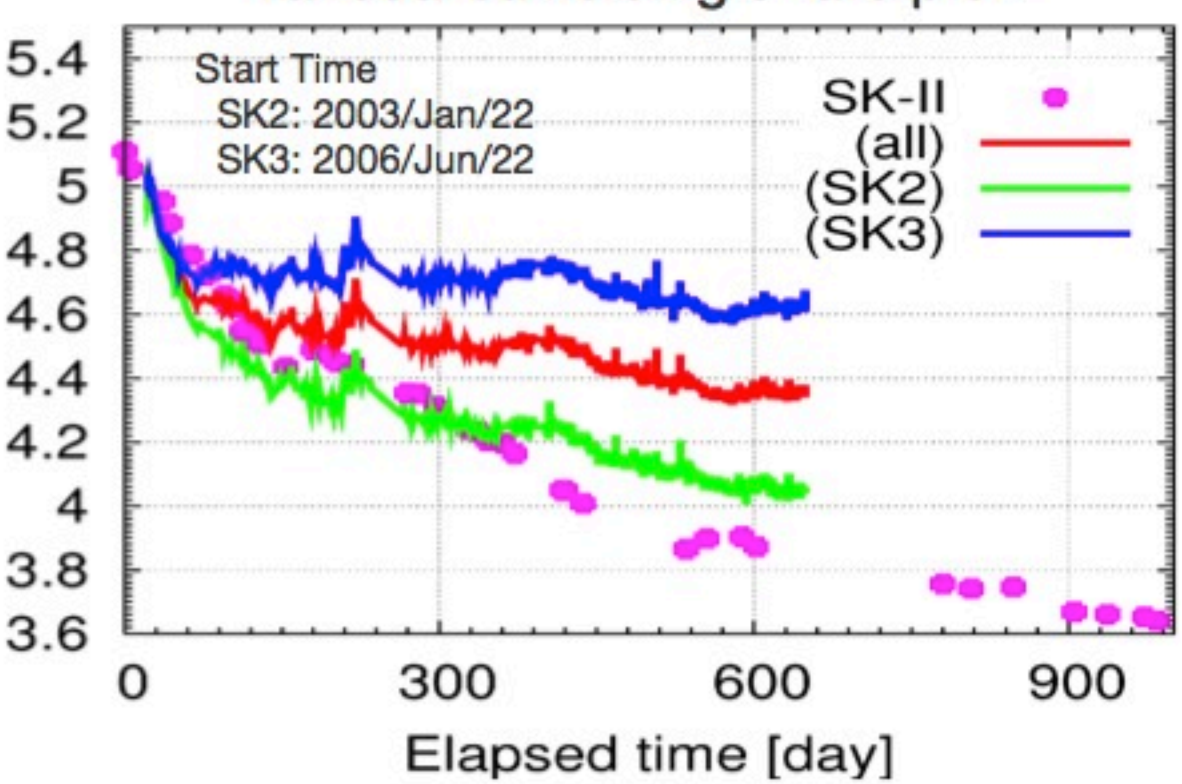
$$\mathrm{Darkrate(kHz)} = \sum_{\mathrm{i=1}}^{\mathrm{n}} \frac{\mathrm{nhit_i}}{\mathrm{n \times 250ns \times nPMT}} \times 10^6$$

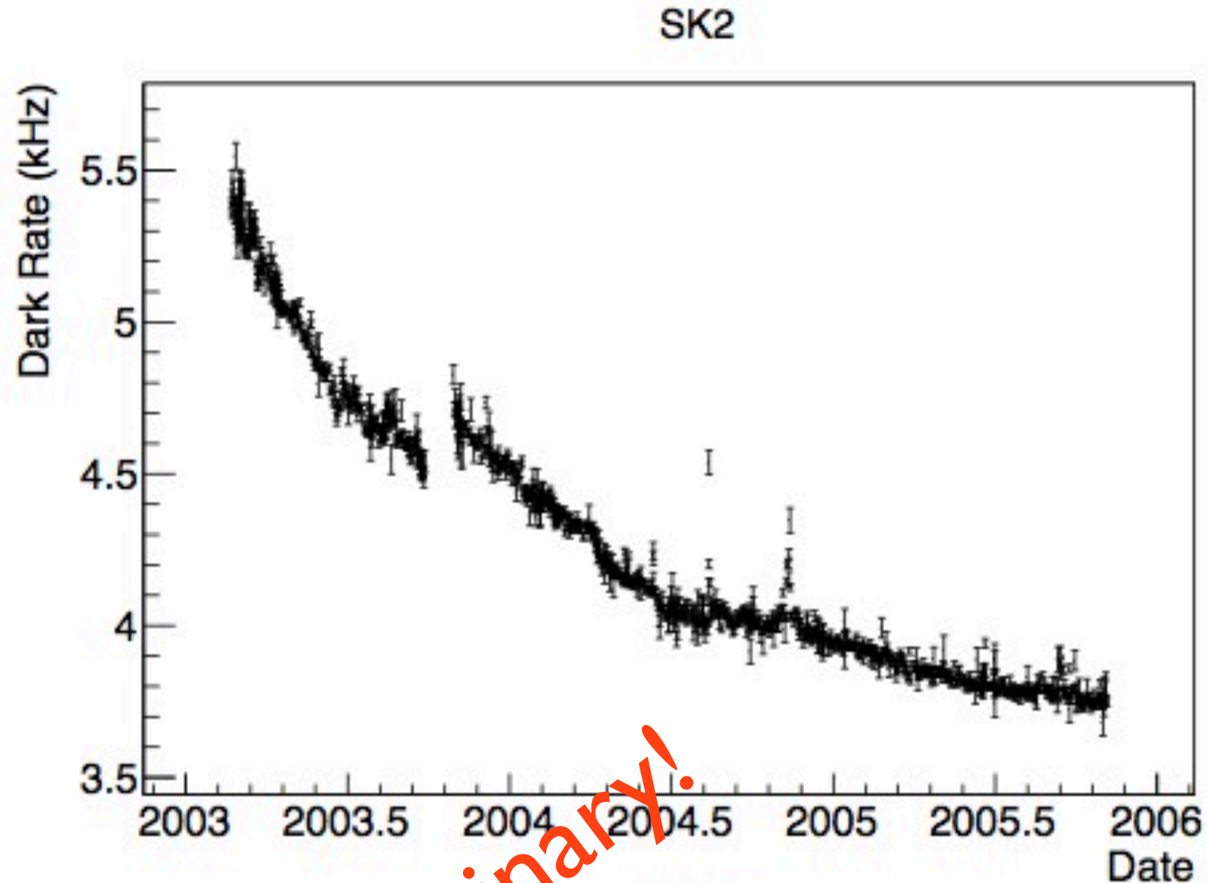
- Instead, take the run-by-run average(using stop-μ)

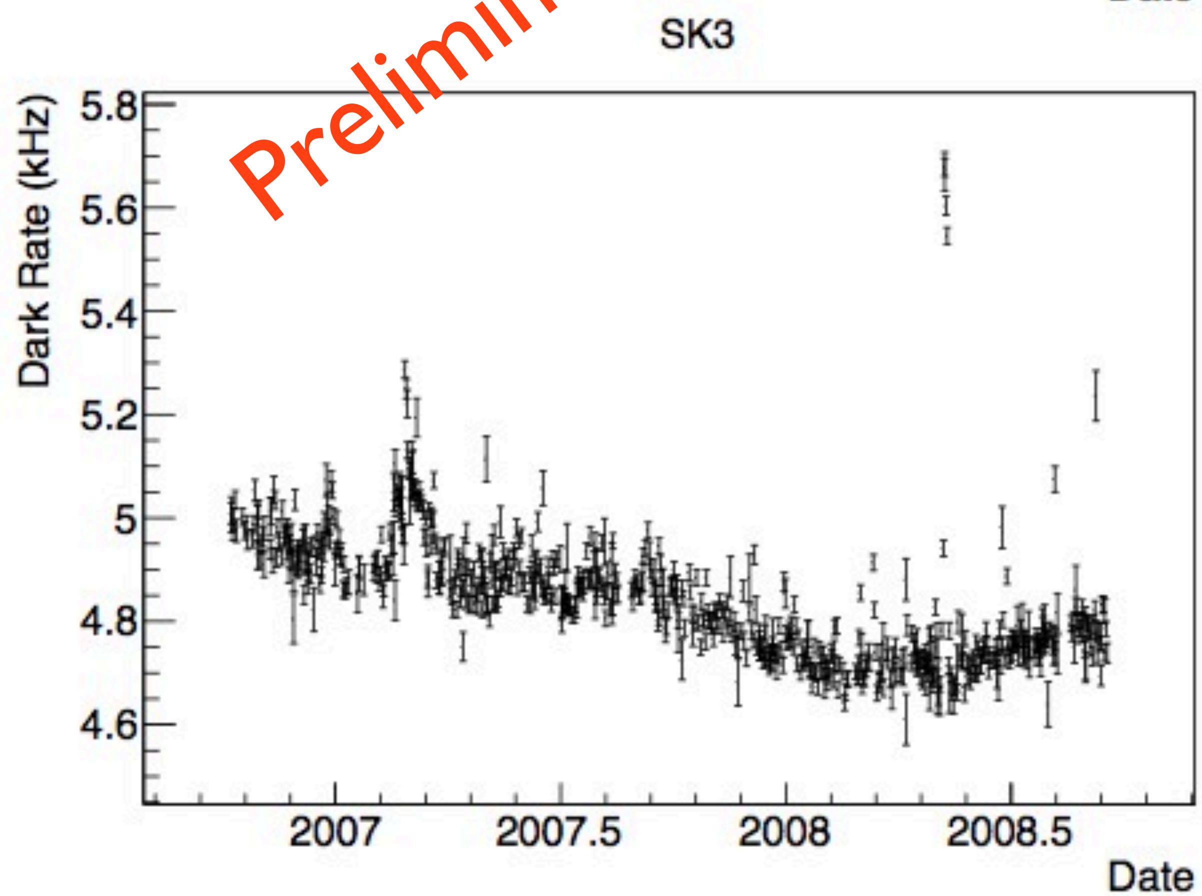
New Dark Rate

- Run by run dark rate plots are generated for SK2&3
- New dark rate is higher than Takeda-san's data,
  but the behavior looks same

Takeda-san's single rate plot







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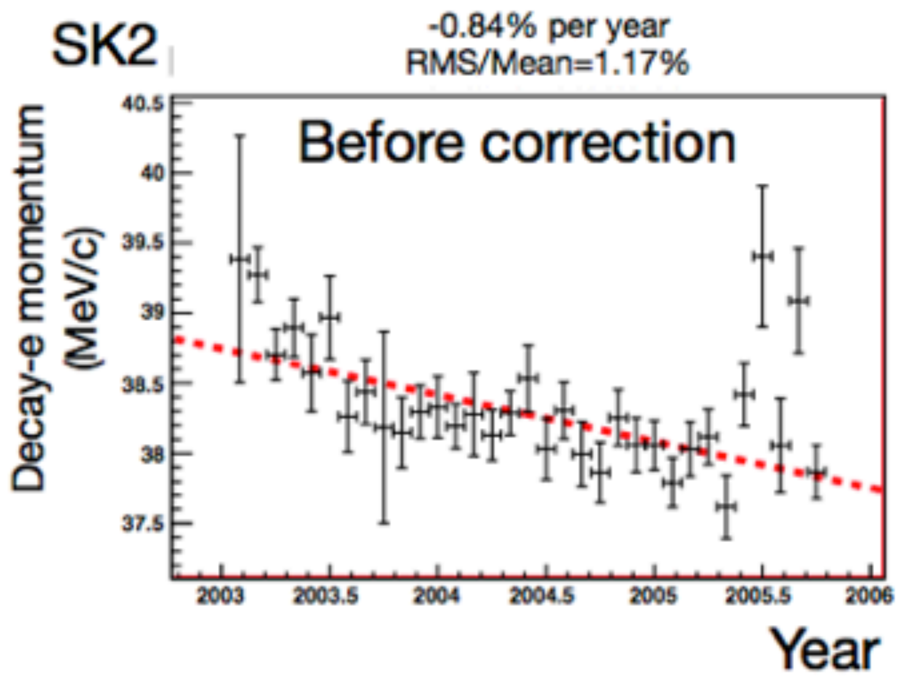
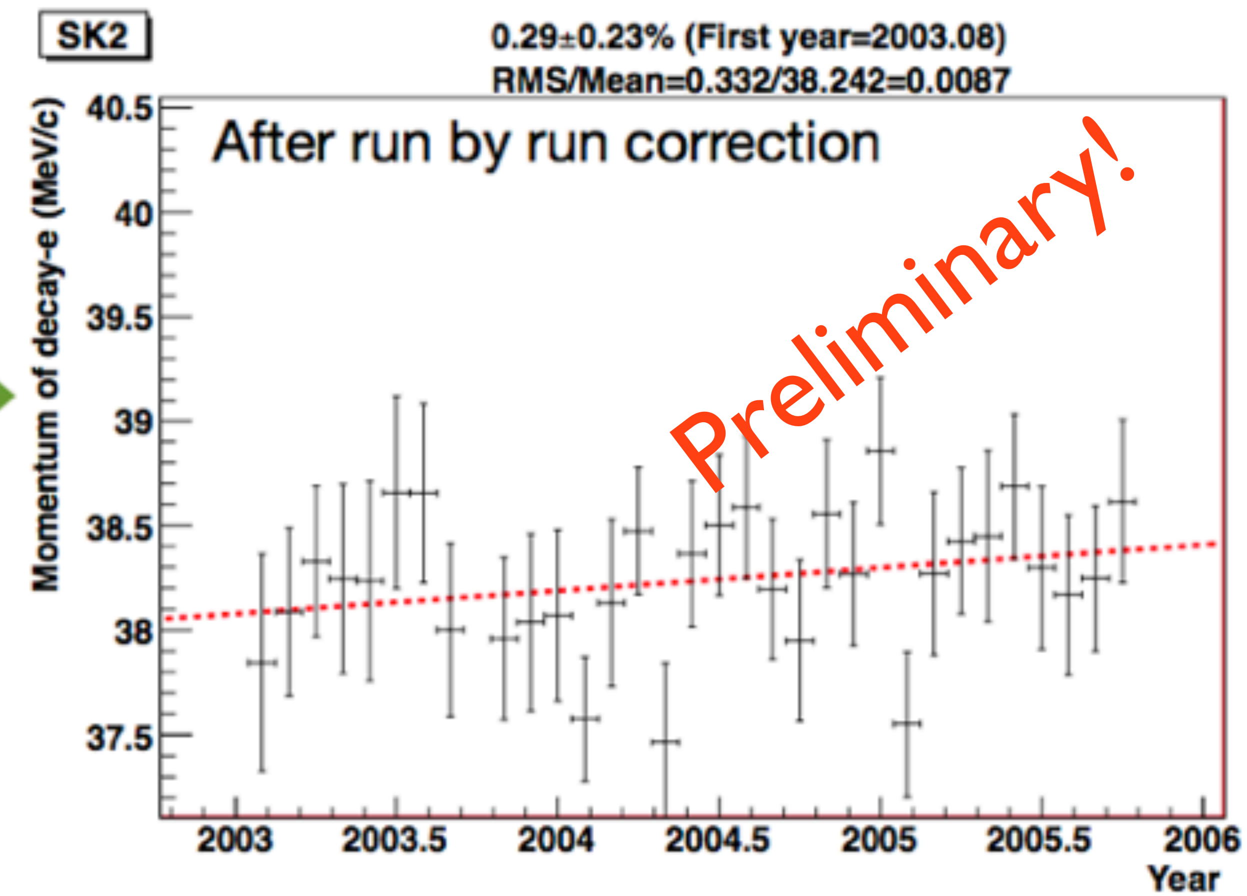
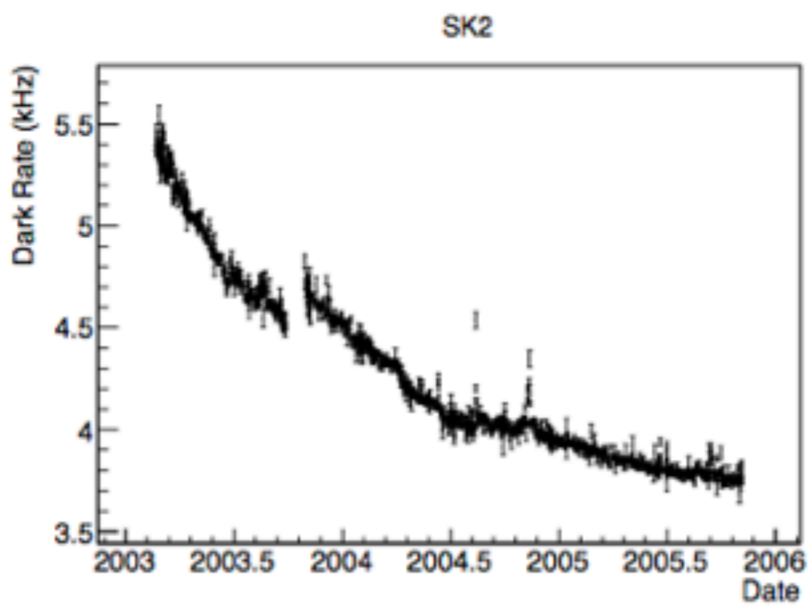
T-var. of Decay-e Momentum





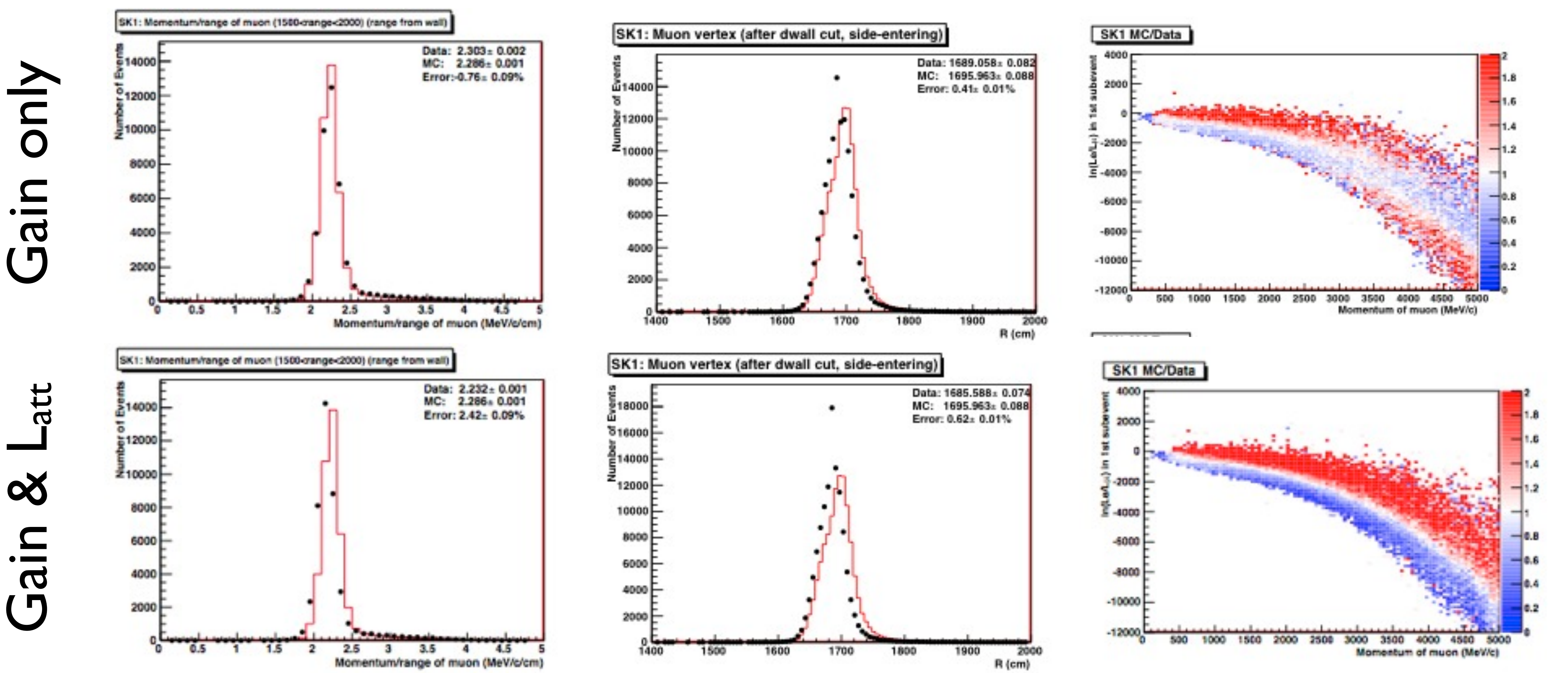


	Before	After
Slope per year	-0.84%	0.29%
RMS/Mean	1.17%	0.87%

- Slope becomes more flat and the error is smaller than before
- The dark rate correction works well!

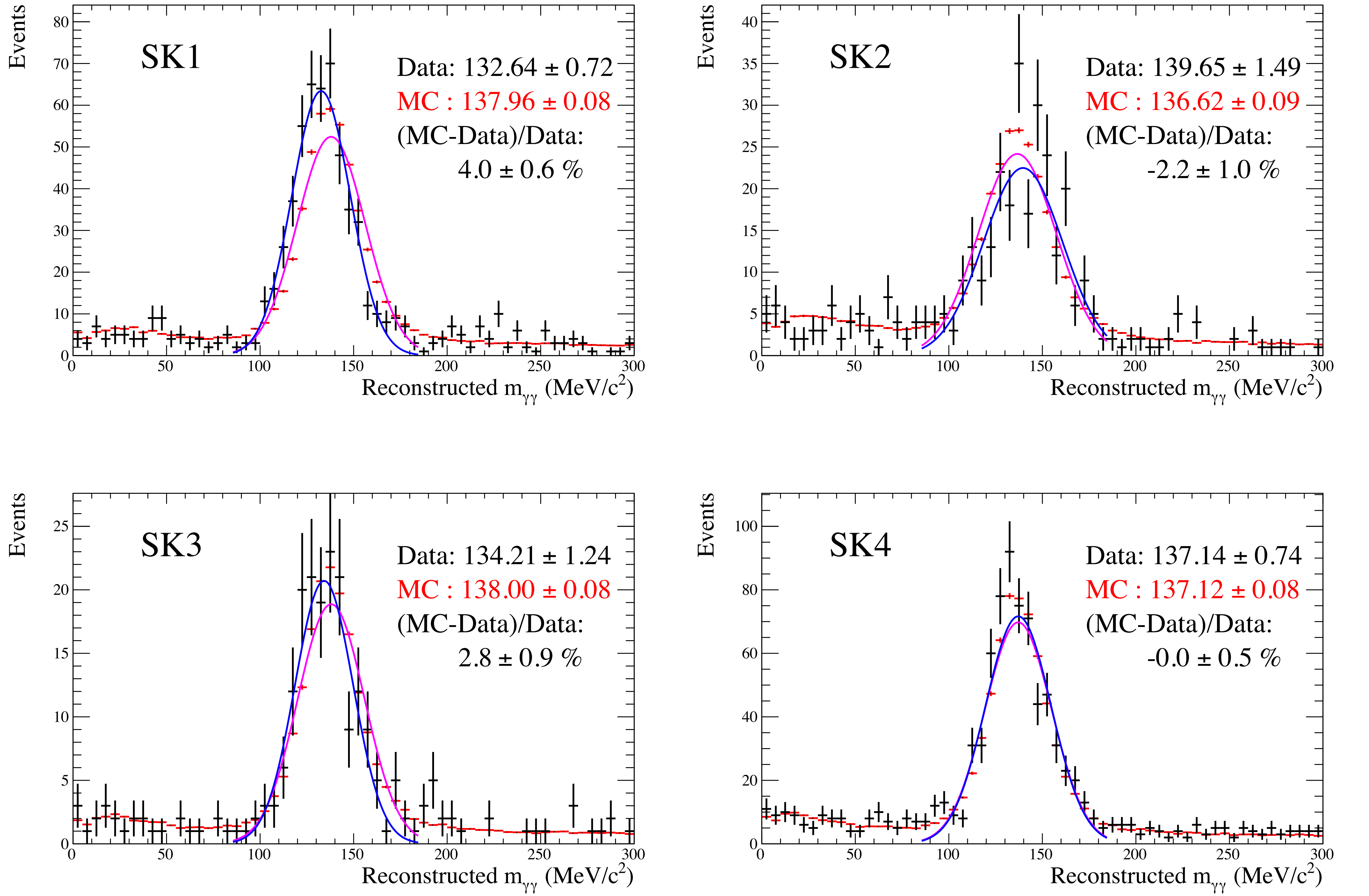
Absolute Data/MC Agreement

- Although time variations of reconstructed variables have stabilized, absolute agreement between data & MC got worse in SK1 by introducing the attenuation length correction
  - Some MC-based study was done to estimate the effect of gain and L_{att} on fiTQun variables(See backup)
  - Although gain & L_{att} tuning will improve the agreement, it is likely that there are other sources(time likelihood, scattered light etc.?) responsible for disagreement



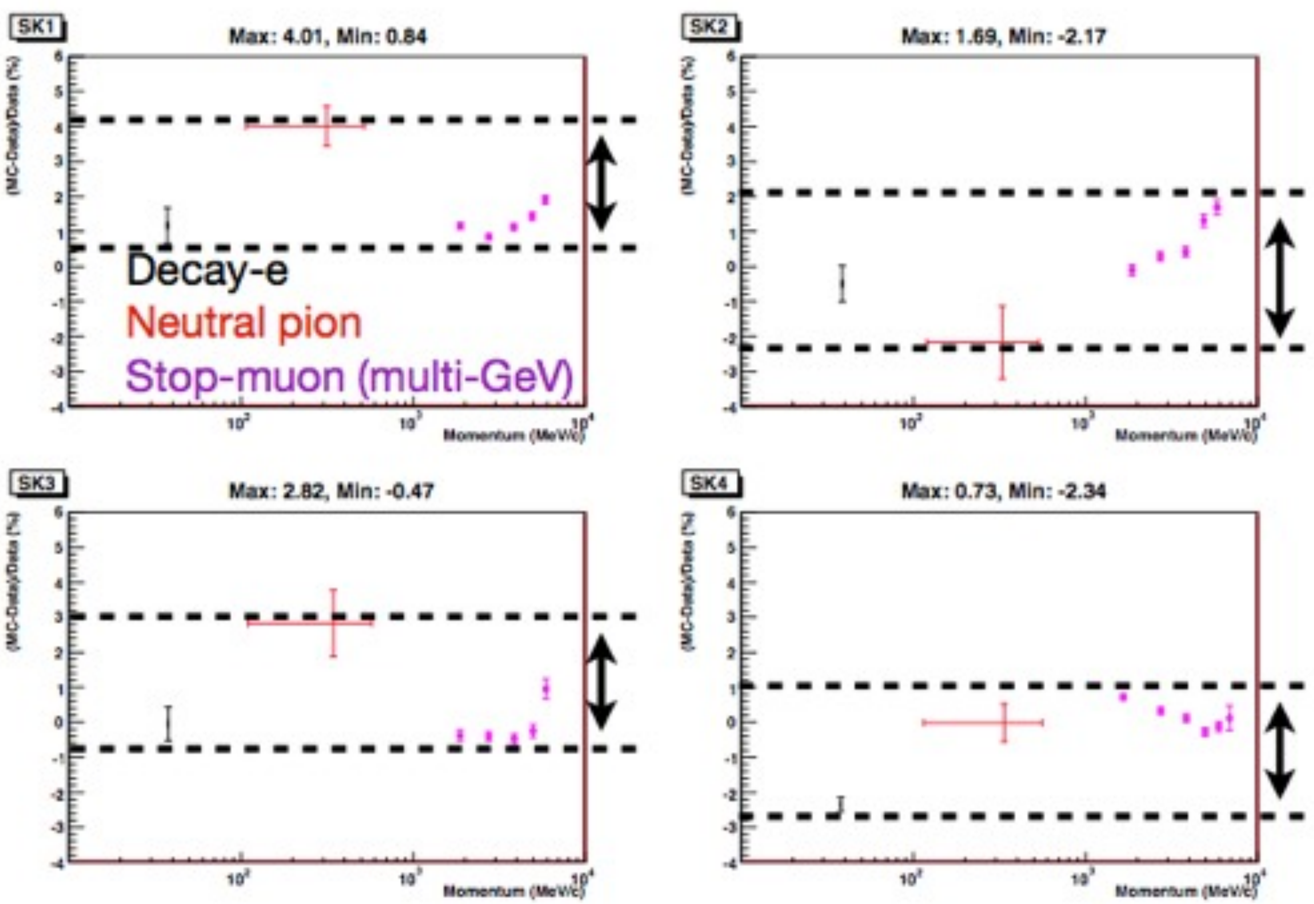
Atm-ν 2Rπ^0 mass

*150323 head version



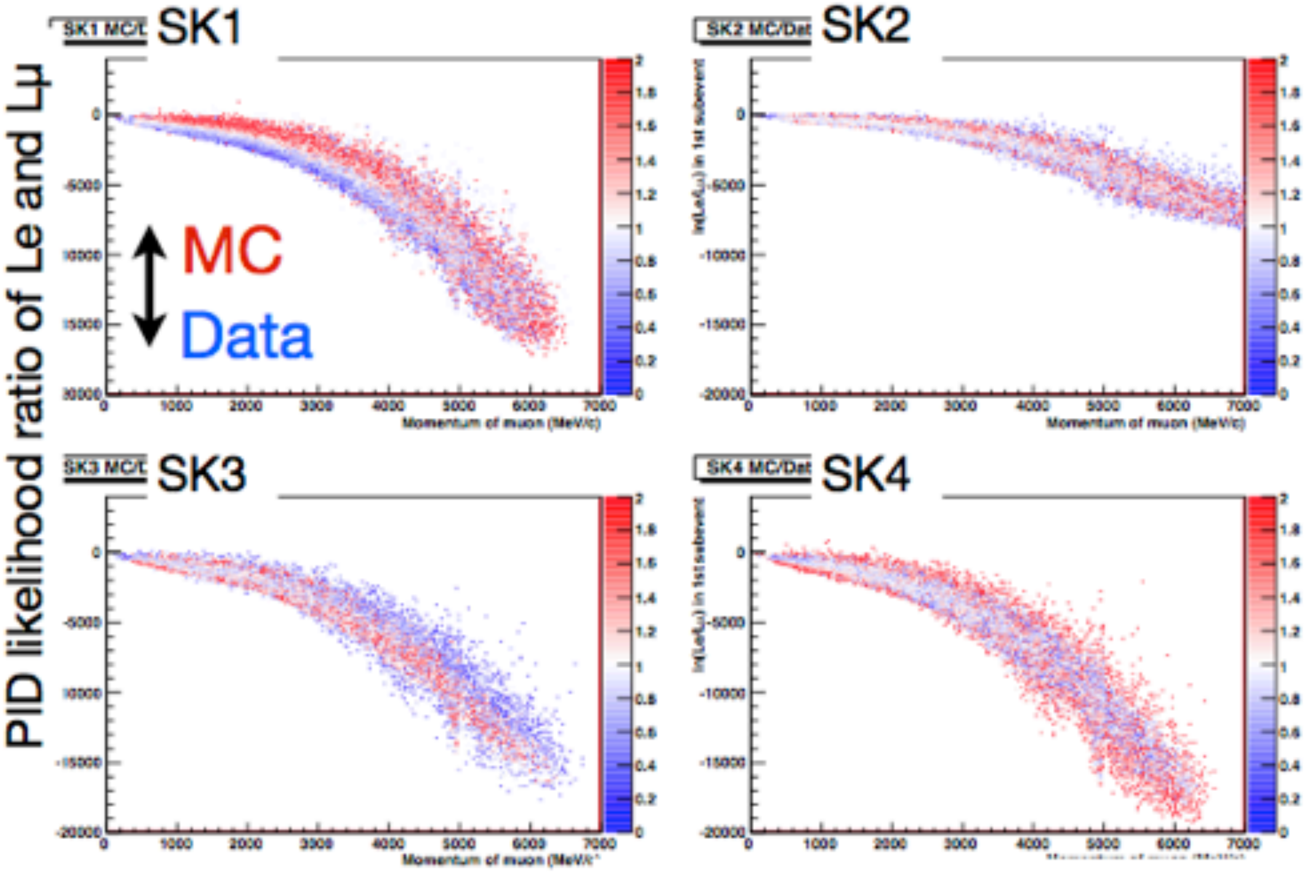
Absolute e-scale

- Depending on the sample, we see different shift of the e-scale between data & MC
- Different mechanism may be involved in π^0
- One of the important next step would be to investigate and understand $m_{\pi 0}$ shift
- Could be related to issues seen in T2K!



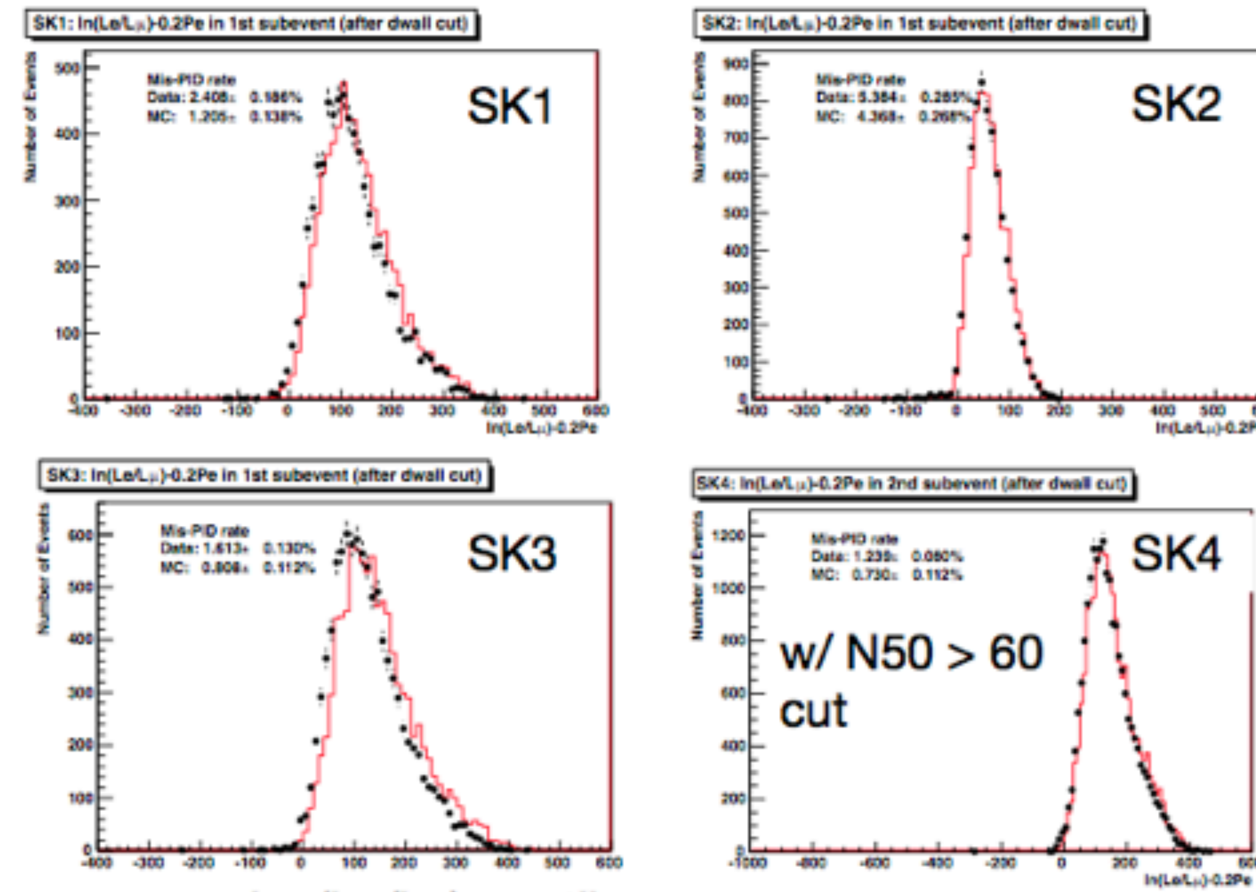
Data/MC Disagreement in PID Likelihood

μ PID likelihood vs. Momentum (MC/Data)



Momentum of muon, Pe (MeV/c)

Decay-e PID likelihood



log(Le/Lμ) - cutline

Mis-PID rate (%)	SK1	SK2	SK3	SK4
Data	0.035	0.015	0.066	0.046
MC	0.084	0.118	0.127	0.051

Mis-PID rate (%)	SK1	SK2	SK3	SK4
Data	2.4±0.2	5.4±0.3	1.6±0.1	1.2±0.1
MC	1.2±0.1	4.4±0.3	0.8±0.1	0.7±0.1

- We found disagreement between data/MC in PID likelihood especially SK1
  - Need to investigate

Summary

- p/range time variations stabilizes over time in all SK1-4, by introducing run-by-run gain & attenuation length corrections on data events
- Variations in dark rate is also being studied
- We see disagreements in absolute agreement of e-scale and likelihoods, especially in SK1,3
  - Somehow gets even worse by the L_{att} corr.
  - Need to understand this!
- π^0 fit disagreement - should collaborate with the T2K effort, as it could have common sources!

Backup

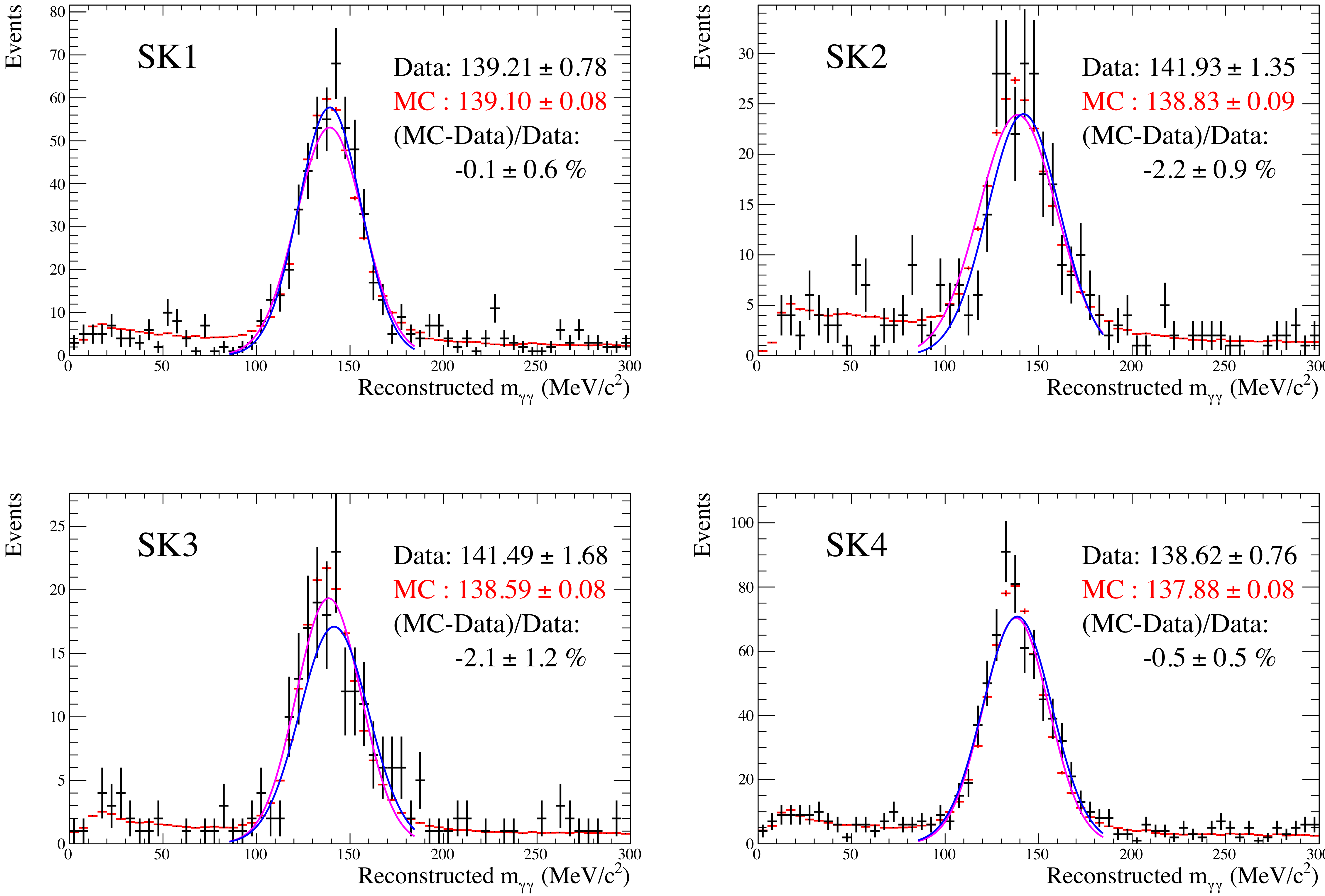
Atm-ν 2R π^0 sample

- Selection using APfit: FCFV 2Ree, 0 decay-e (same as official sample)
- Data: Livetime=[1489.2, 798.6, 518.1, 1993.6]
  - SK1-3 Oct11: 11d library
  - SK4 Oct14: 14c library
- MC:
  - SK1-3: Oct11: 11d, SKDETSIMv12p80
  - SK4: Mar13: 13a, SKDETSIMv13p80
  - New 14a SK1-3 MC with SKDETSIMv13p90 has been deleted...
- All stop-μ MC is 14a/v13p90 - could be issues when comparing
  - v13p80: Tarek's tuning(only for SK3/4), photonuclear effect
  - v13p90: Tarek's tuning is undone? (unless WATERP==201208), corepmt*=0.9925 for SK4

APfit

Jose May ’14(14a?)→

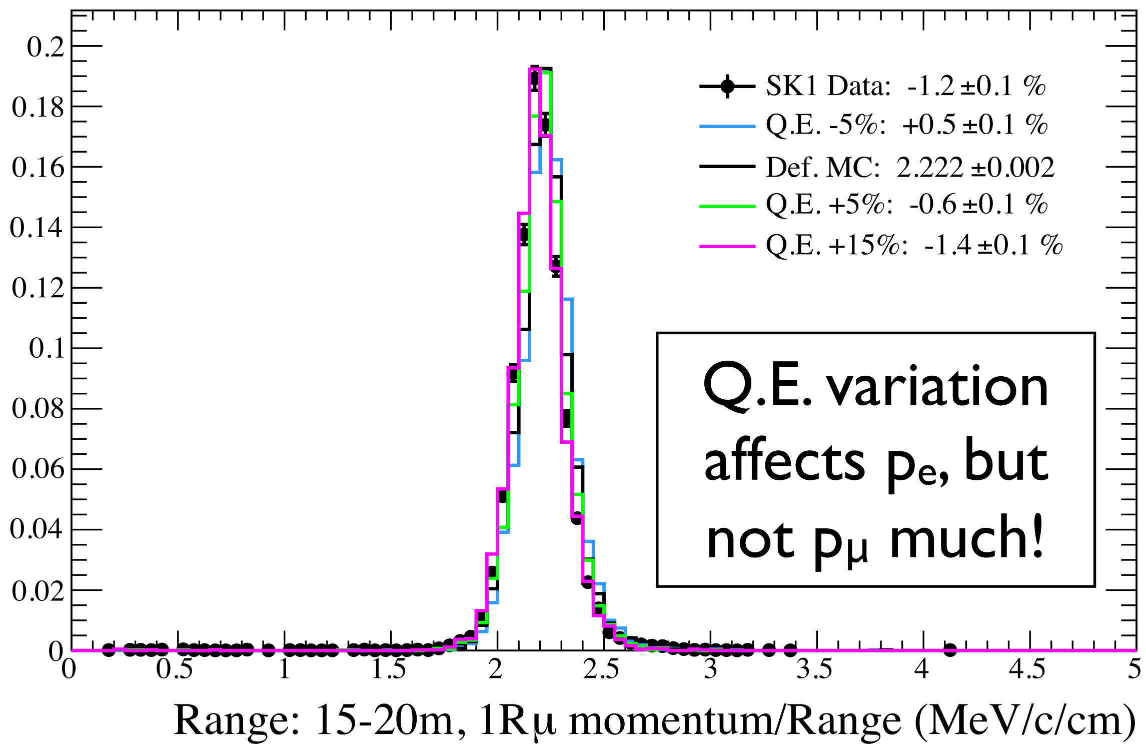
	14a Lib	Ishihara-san
SK-I	-0.3+/-0.6	-0.7
SK-II	-2.7+/-0.9	-1.3
SK-III	-0.9+/-1.1	-0.3
SK-IV	0.9+/-0.6	—

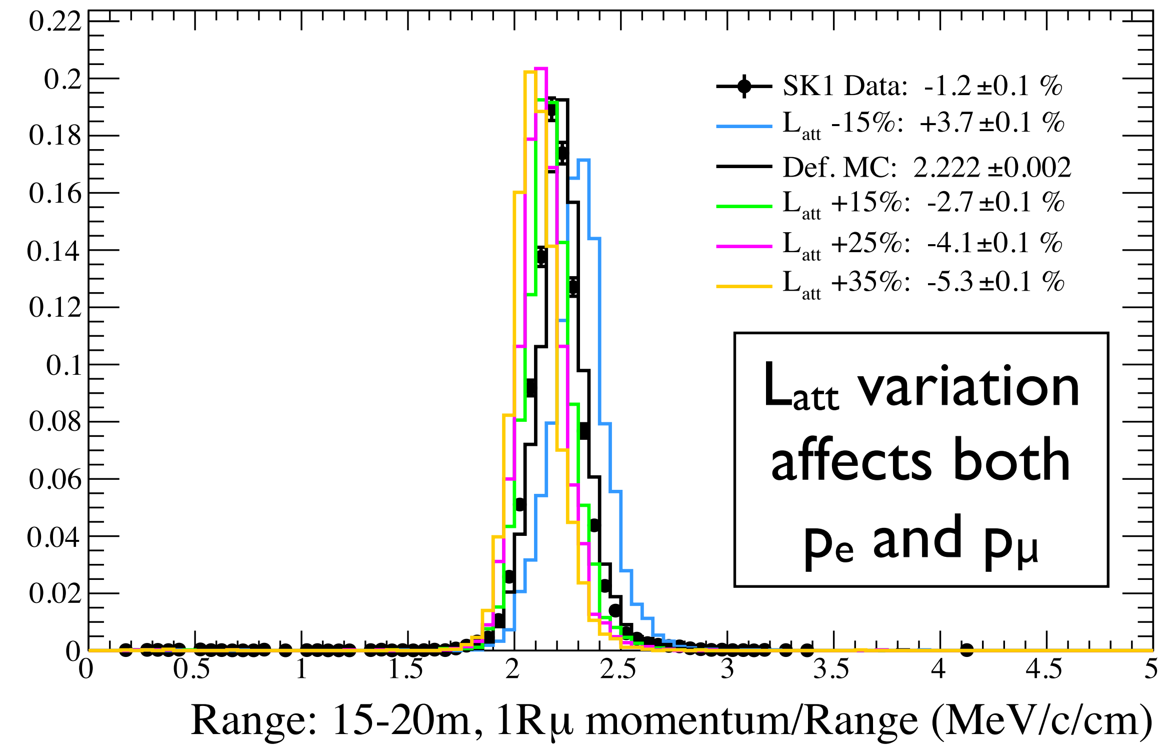


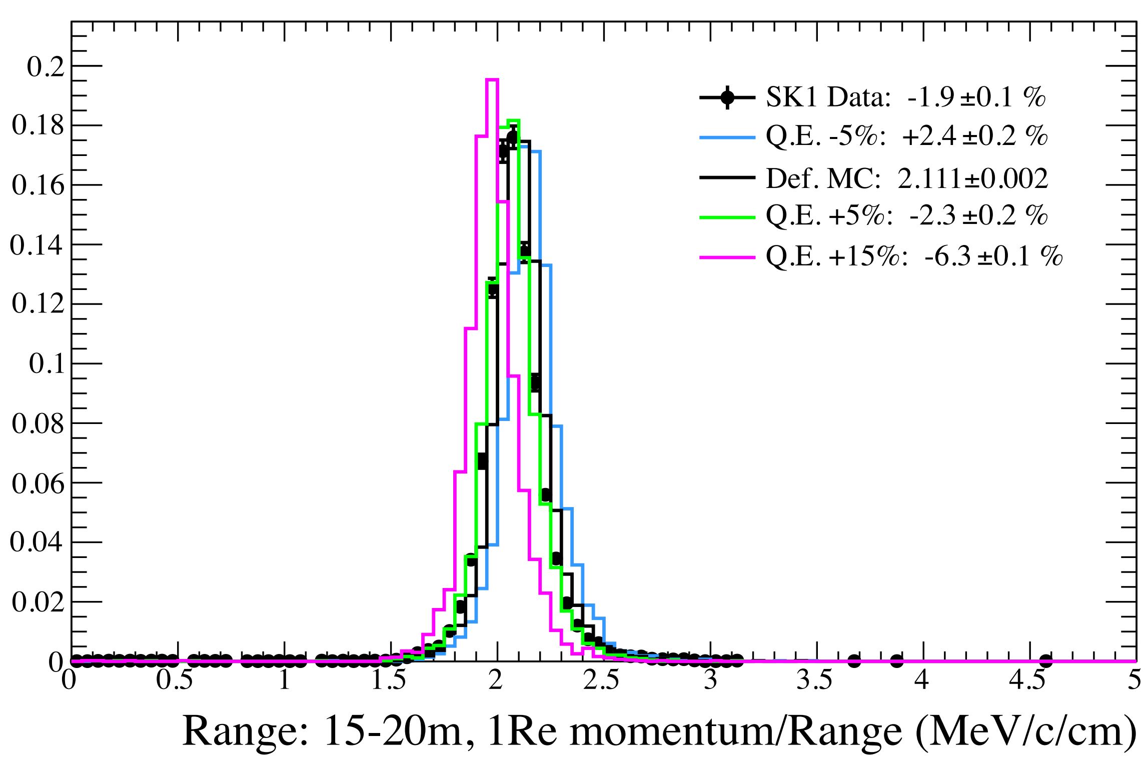
Momentum/Range

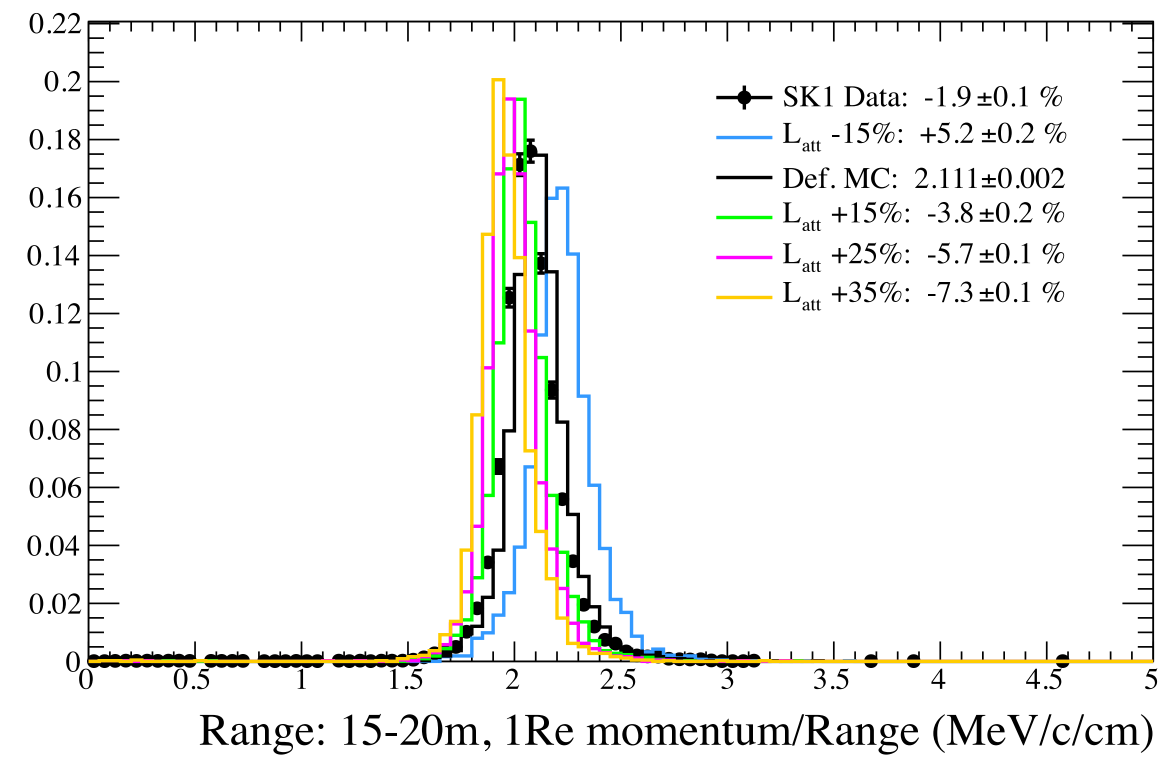
Q.E. variations

L_{att} variations





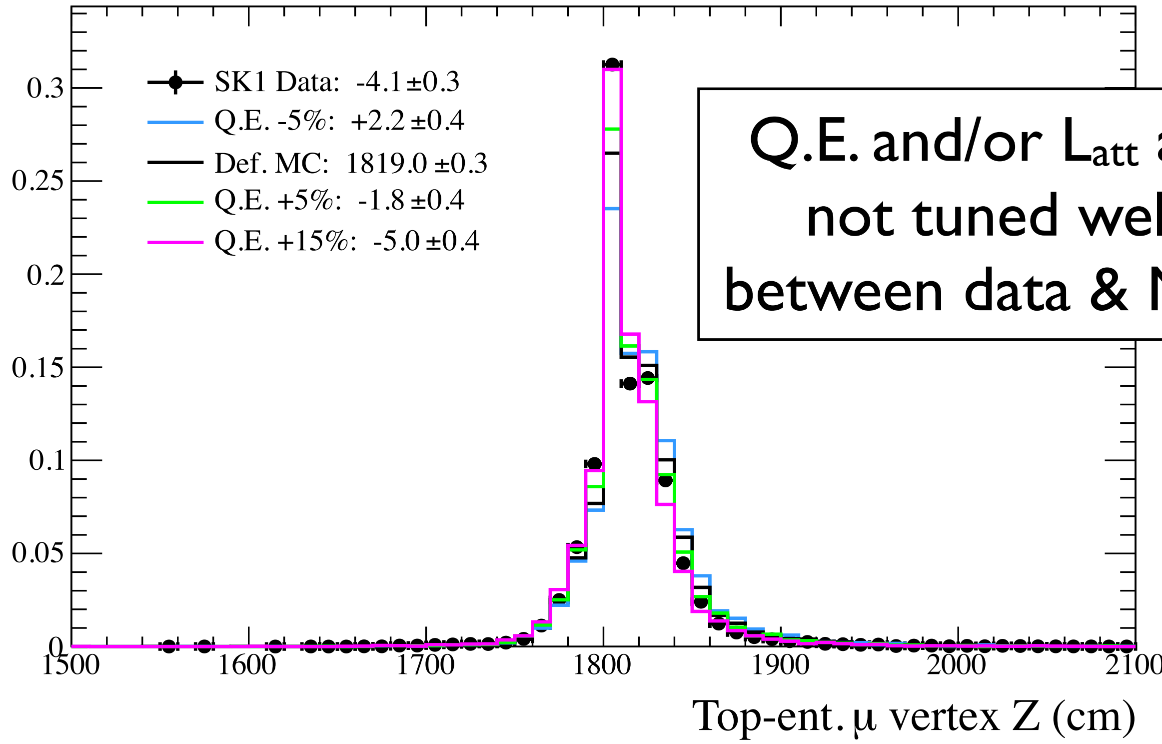




L_{att} correction for SK1 data introduced
overall ~20% increase in L_{att} for data
Explains the shifts observed between
the cases w/ & w/o L_{att} correction

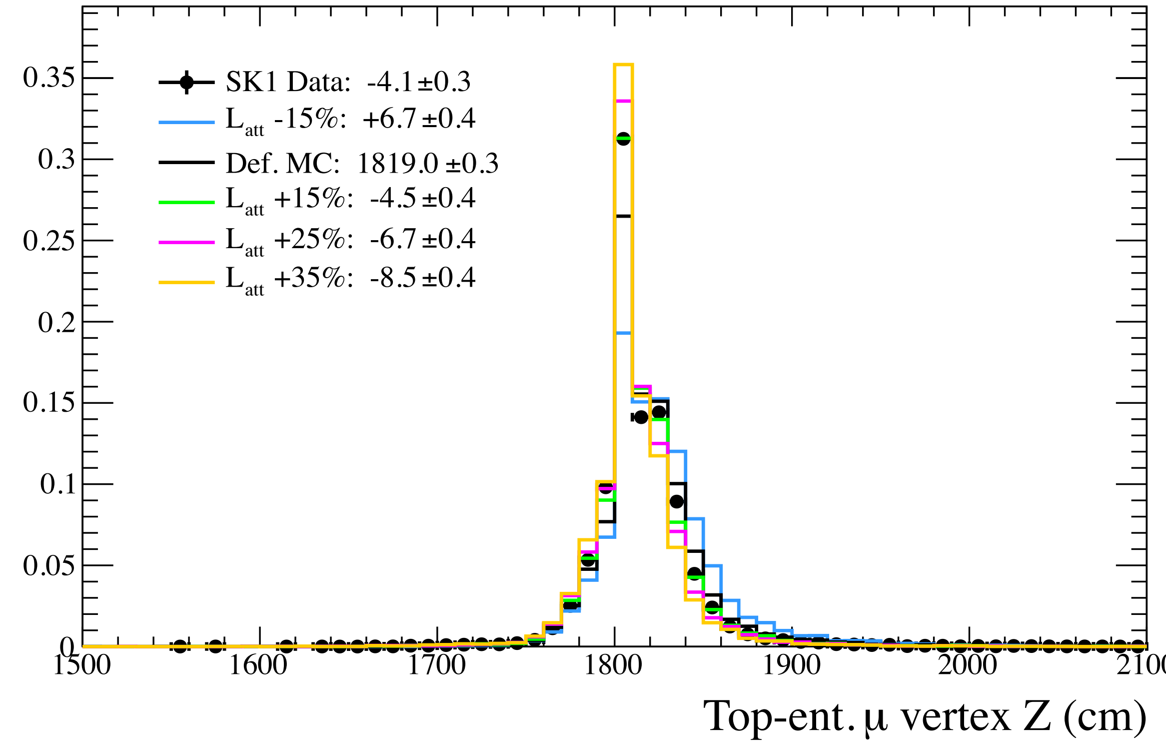
Muon Vertex

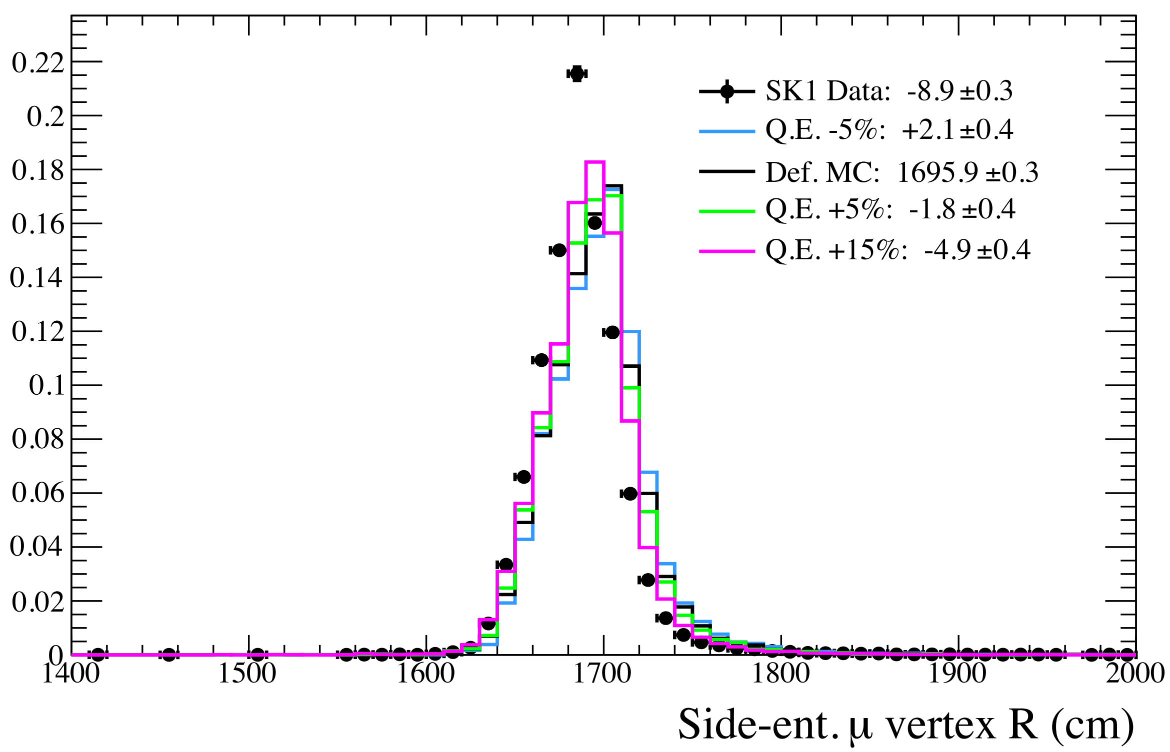
Q.E. variations



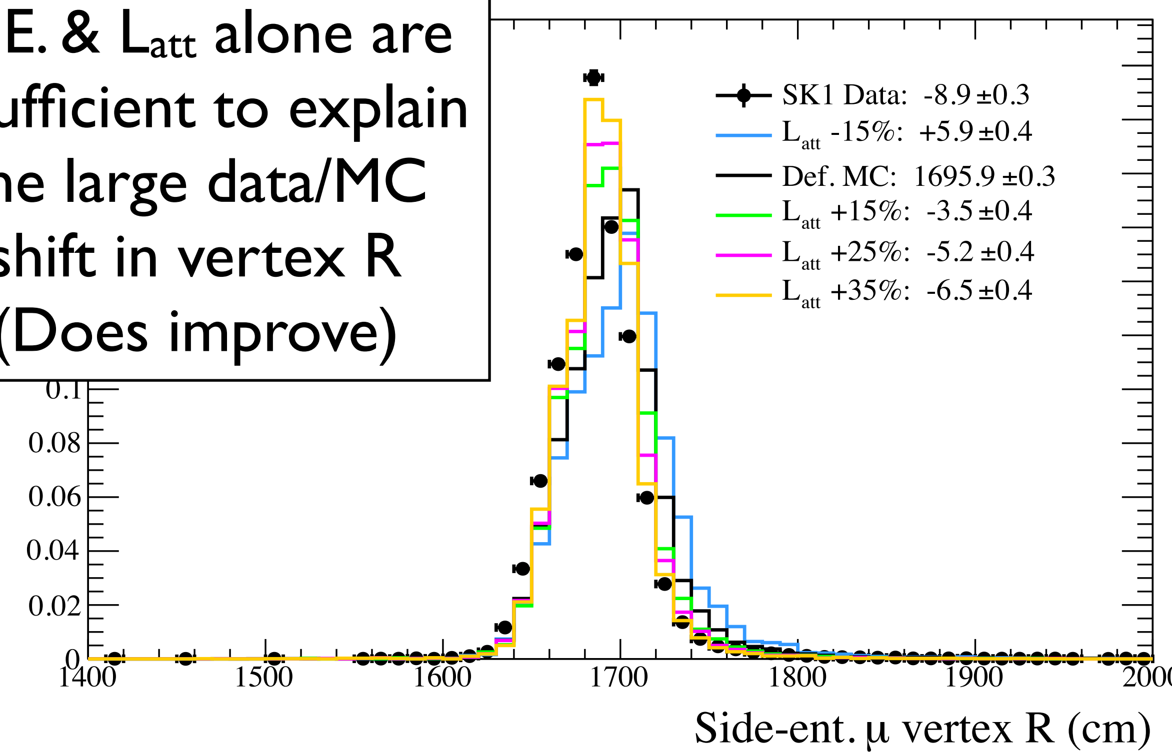
Q.E. and/or L_{att} are not tuned well between data & MC?

L_{att} variations



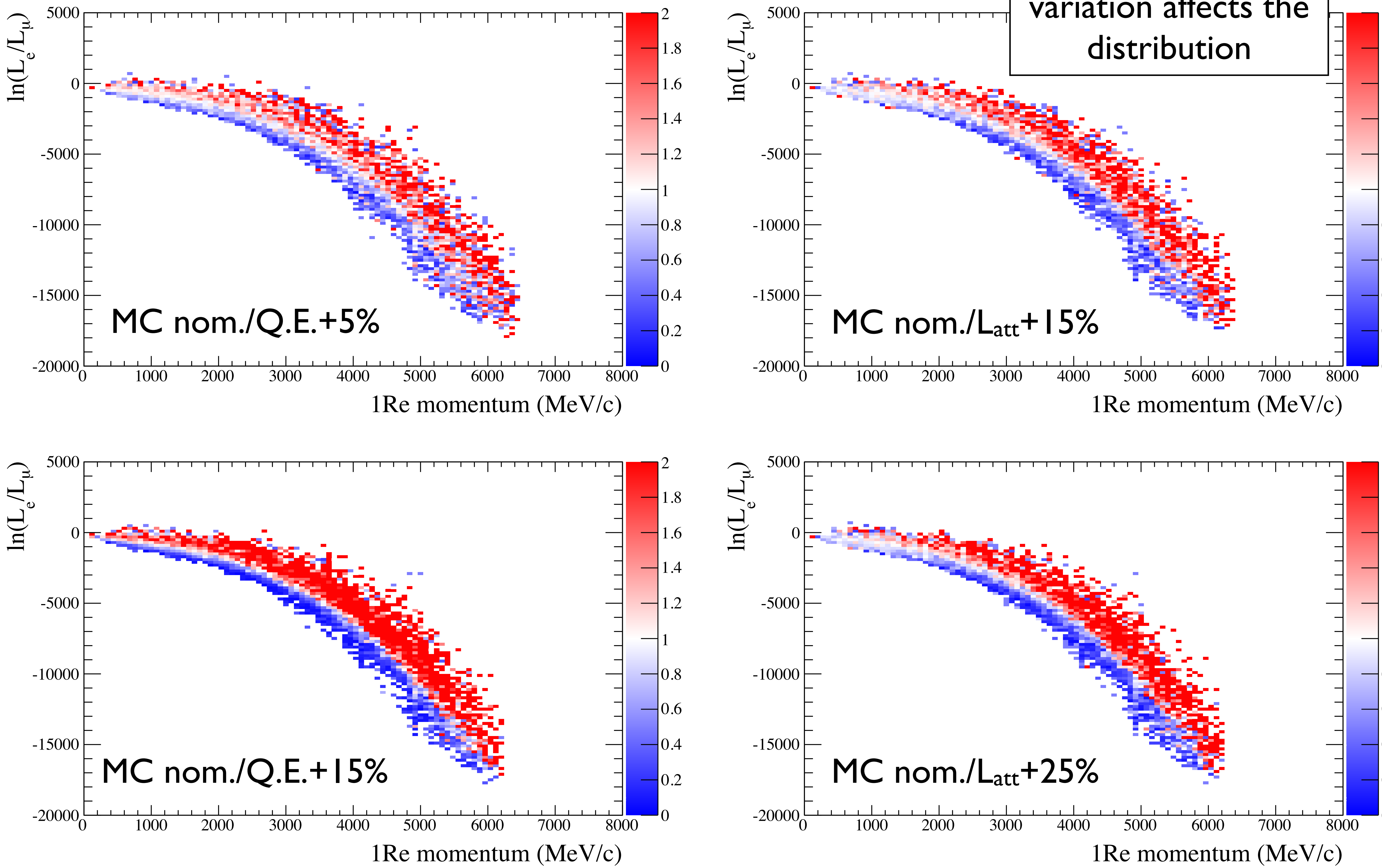


Q.E. & L_{att} alone are insufficient to explain the large data/MC shift in vertex R (Does improve)

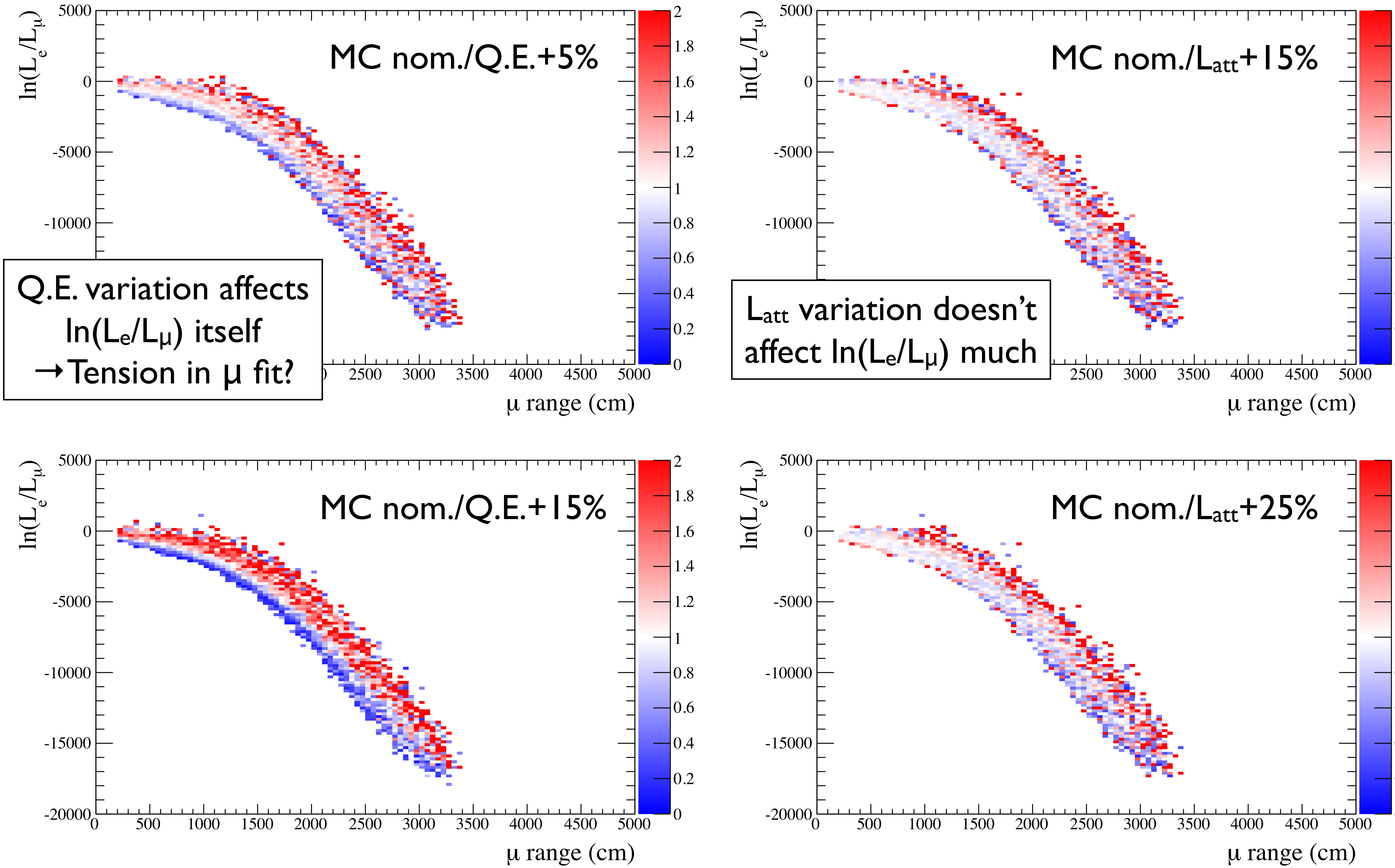


$\ln(L_e/L_\mu)$ vs. p_{1Re}: MC Variations

Both Q.E. & L_{att} variation affects the distribution



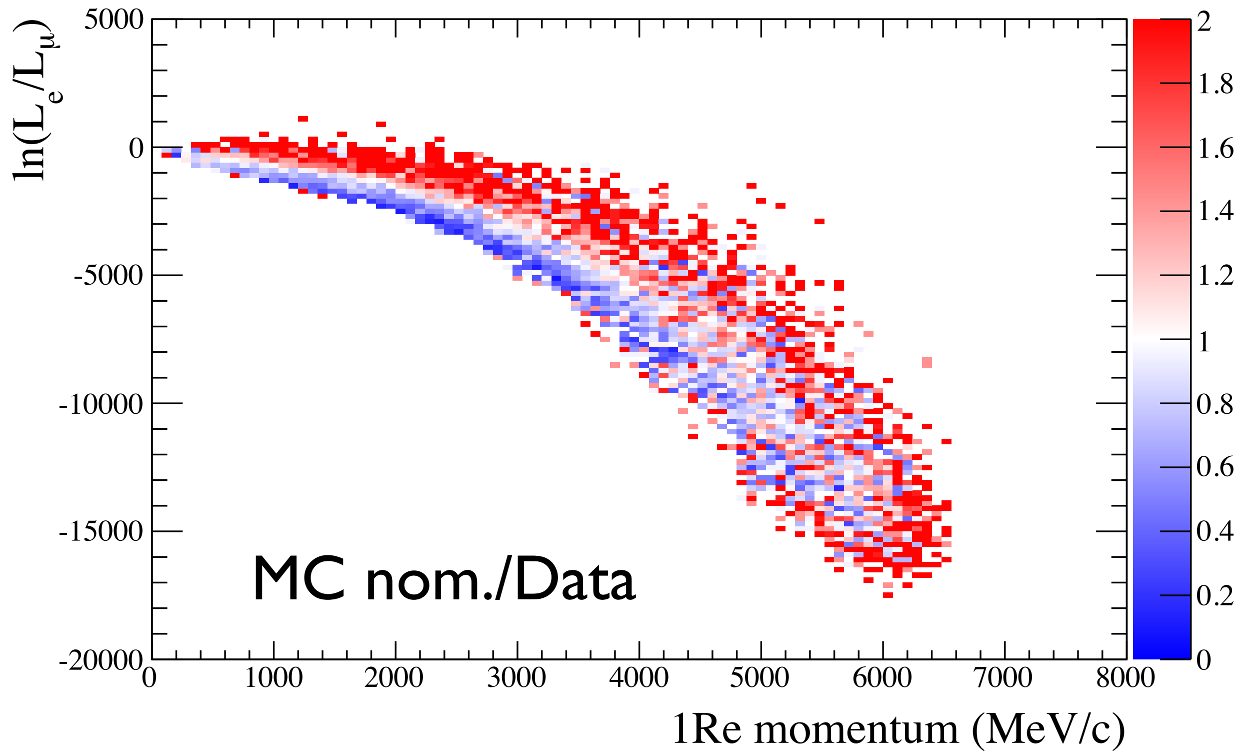
ln(Le/Lμ) vs. Range: MC Variations



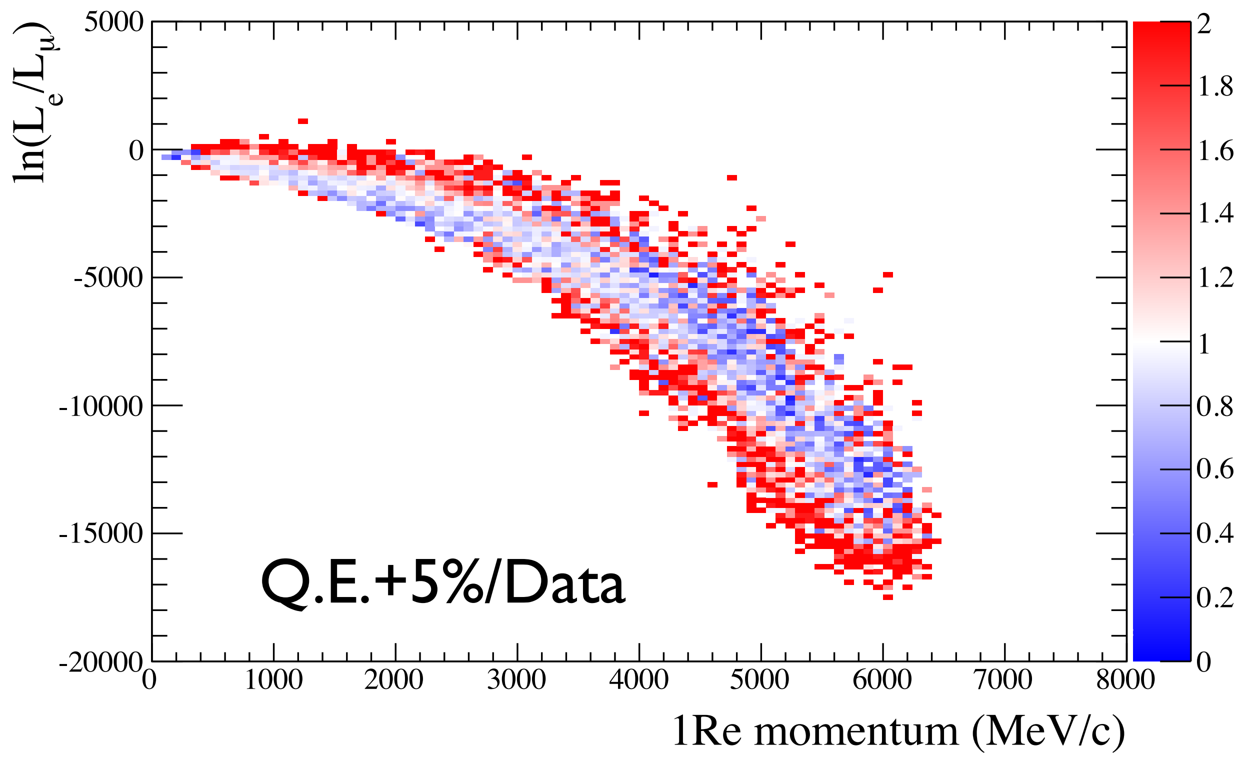
Q.E. variation affects ln(Le/Lμ) itself
→Tension in μ fit?

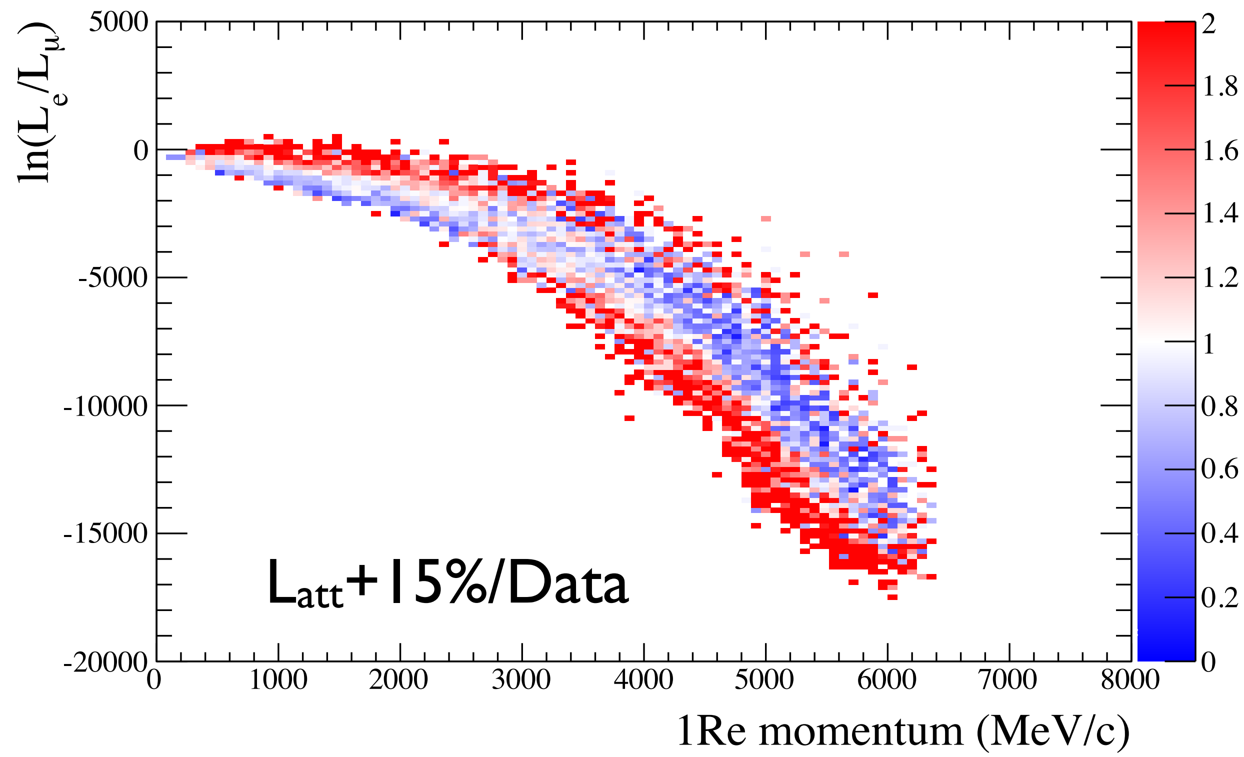
Latt variation doesn't affect ln(Le/Lμ) much

$\ln(L_e/L_\mu)$ vs. p_{1Re} : MC/Data

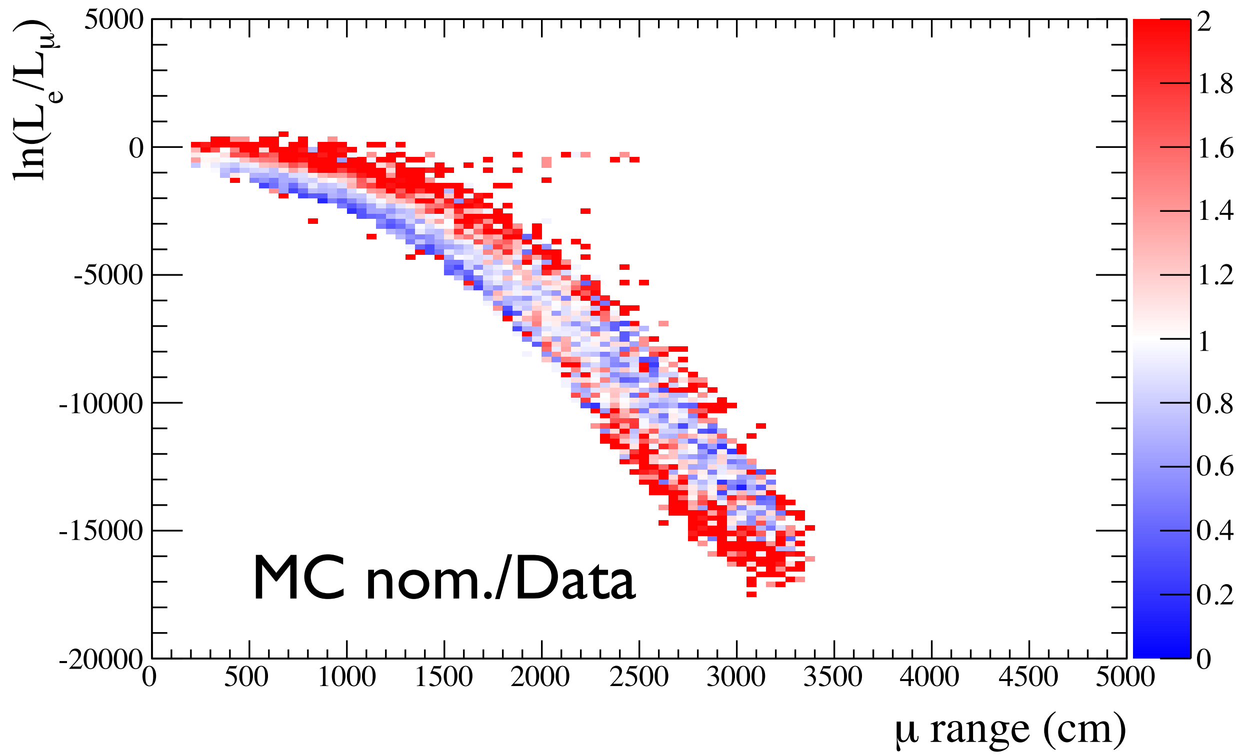


- Changing L_{att} or Q.E. improve data/MC agreement, but cannot fully explain the shift
  - Momentum agreement gets improved

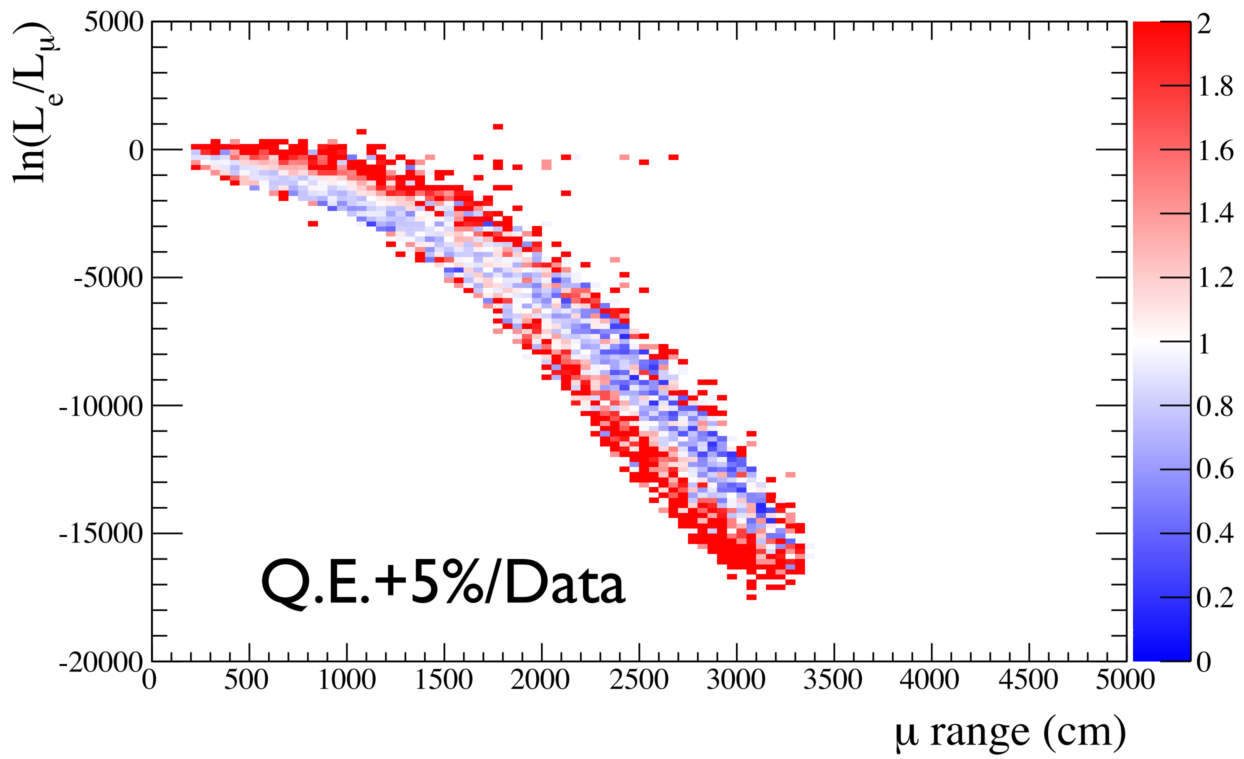


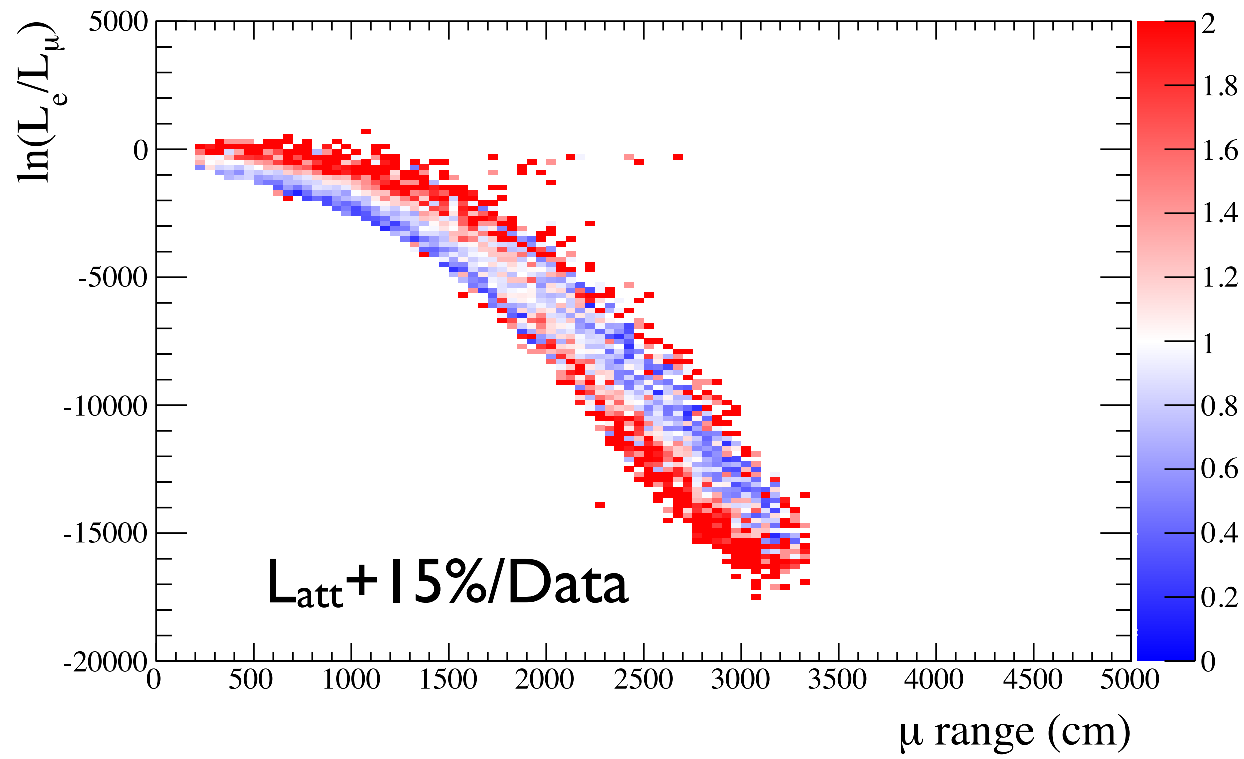


ln(L_e/L_μ) vs. Range : MC/Data



- Changing L_{att} does not make data/MC agree better
- Changing QE does improve data/MC agreement, but cannot fully explain the shift





Decay-e Improvements

- Decay-e reconstruction has been improved - See backup for detail
- Fit failures on decay-e from multi-GeV muon has been significantly reduced
- Fake decay detection rate has also decreased - similar to muechk level
- Decay-e time window is treated in the same way as the primary time window
    - Allows more proper evaluation of PID systematics using decay-e