Near detector Data-MC Comparison for FHC & RHC modes with the JINR interaction model

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Introduction

We review the GENIE tuning and calculation method for description of the (anti)neutrino-induced events rates recorded in the NOνA ND at (anti)neutrino energies above ~ 1 GeV.

Outline:

- Model and method updates
- Comparison of models with the ND data in FHC & RHC modes
- Future plans and proposal

Model and method updates

All needed details about GENIE tuning and method of event rates calculation can be found in docs 16335 and 23018 (a bit dated). Here we turn our attention only to what were changed since last analysis.

- Two new additions to the previous JINR-tuned GENIE were made: BBBA07 form factor model (instead of BBBA05) and Pauli blocking for 1π resonance production.
- Now, the full JINR model is implemented in local (JINR) version of GENIE, but it will be included into the future official GENIE 3.0.0 release.
- We can't simulate events directly so we use the procedure of reweighting MC events. The calculation of weights was changed drastically since previous analysis. As before we compute weights as ratios of the cross sections calculated with the JINR and original GENIE used in NOνA (both are based on version 2.12.8), but now we account for the ND chemical "soup" composition (doc 23132-v3), use real (anti)neutrino fluxes(doc 25266-v5) and generate events with FSI.

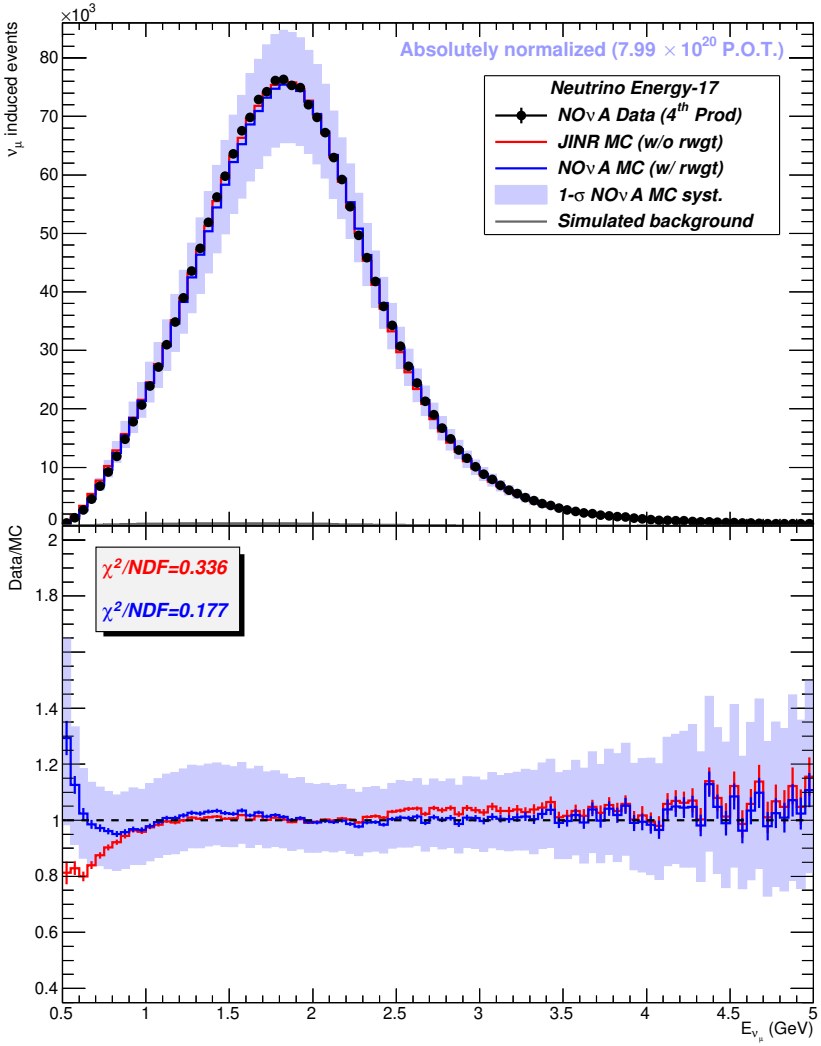
ND data comparison

- CAF (release S18-05-06)
- Forth production neutrino datasets (MC & Data):
  prod_caf_R17-11-14-prod4reco.d_nd_genie_nonswap_fhc_nova_v08_full_v1
  prod_caf_R17-09-05-prod4recopreview.f_nd_numi_fhc_full_v1_addShortSimpleCVN_goodruns
- Forth production antineutrino datasets (MC & Data):
  prod_caf_R17-11-14-prod4reco.e_nd_genie_nonswap_rhc_nova_v08_full_v1
  prod_caf_R17-09-05-prod4recopreview.f_nd_numi_rhc_full_v1_addShortSimpleCVN_goodruns
- kStandardSpillCuts
- kCCE, kMuE, kCosNumi, kHadE, kRecoQmag, kRecoQ2, kRecoW
- kNumuCutND2018, kNumuCutND2017Prod4
- kXSecCVWgt2018*kPPFXFluxCVWgt
- Simulated background:
  kNumuCutND2018 && !kIsNumuCC, kNumuCutND2017Prod4 && !kIsNumuCC
- Band: getAna2018LargeXsecSysts(kNumuAna2018)
- $\chi^2/\text{NDF} = \sum_{\text{bins}} \frac{(\text{Data}/\text{MC}-1)^2}{\sigma^2_{\text{stat}}+\sigma^2_{\text{syst}}}/\#\text{bins}$, where we suppose (off the top of our heads) $\sigma_{\text{syst}} \approx 0.1$.

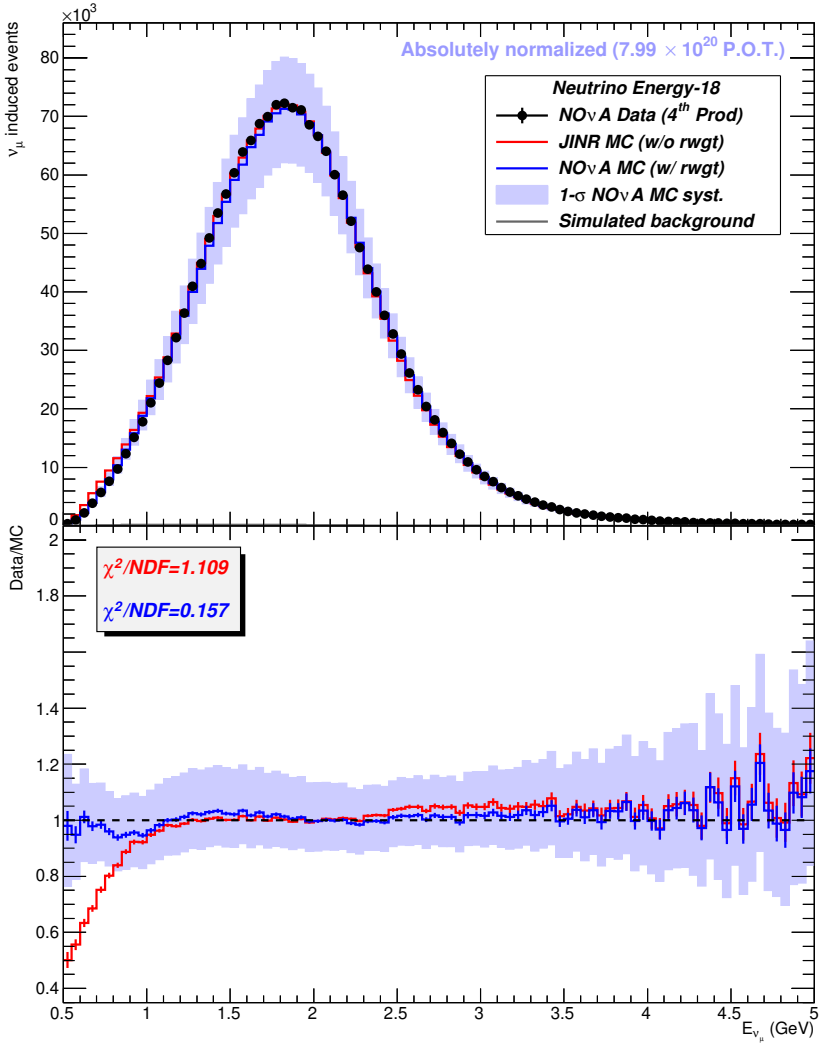
ND data comparison (FHC mode)

Neutrino energy

kNumuCutND2017Prod4



kNumuCutND2018



ND data comparison (FHC mode)

Neutrino energy

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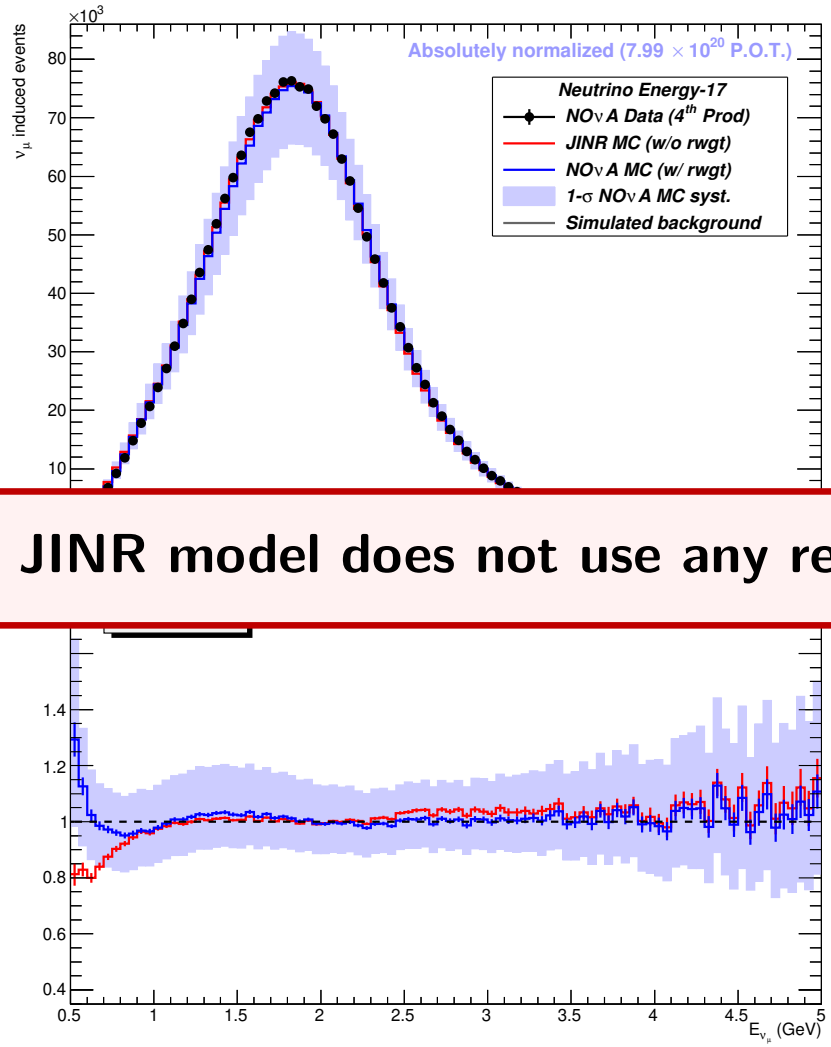
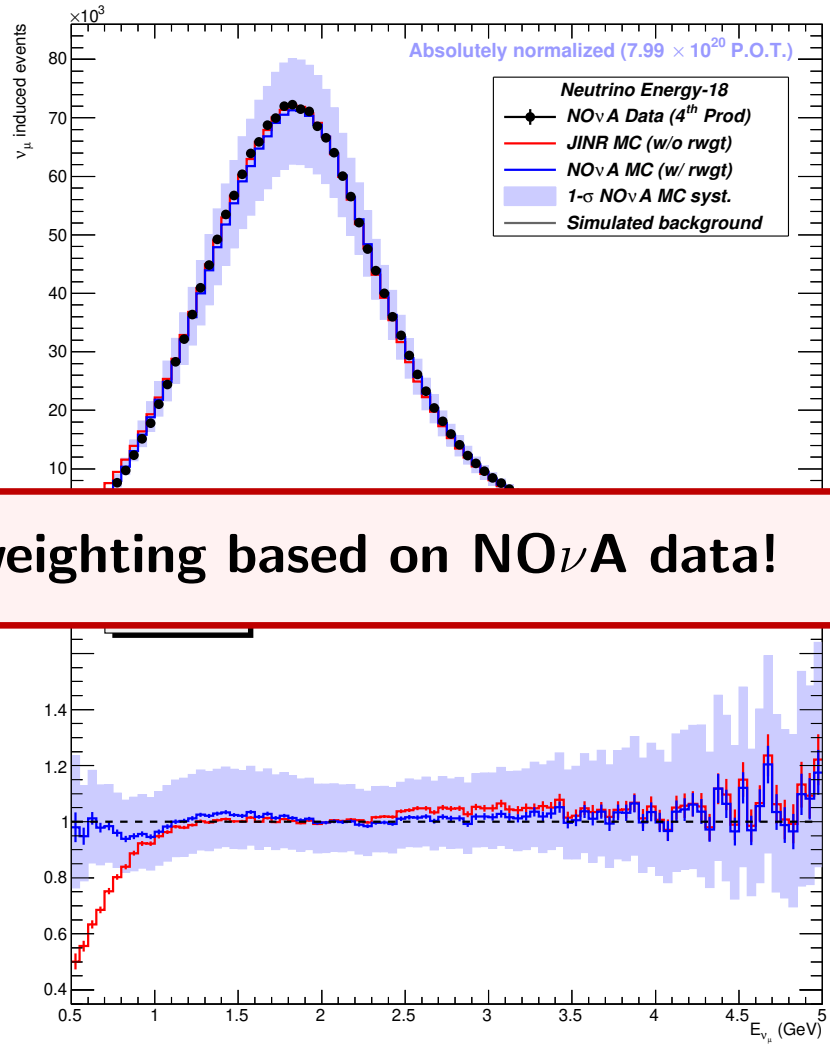


kNumuCutND2018

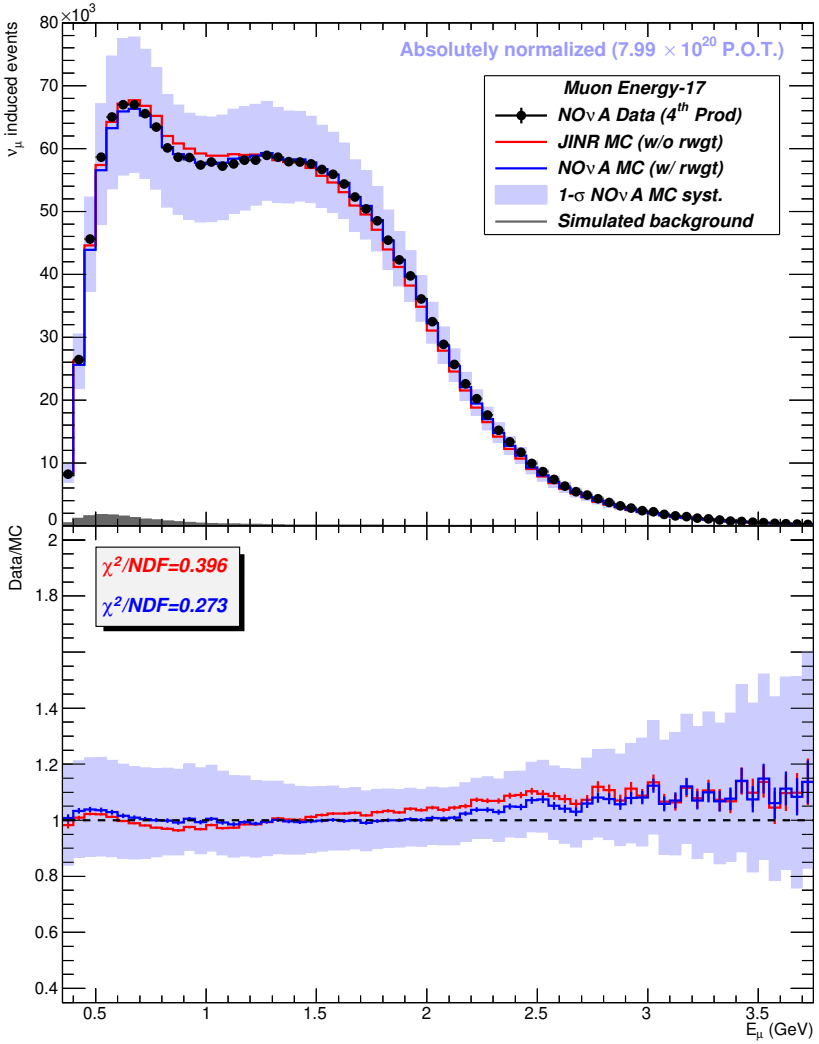


JINR model does not use any reweighting based on NOνA data!

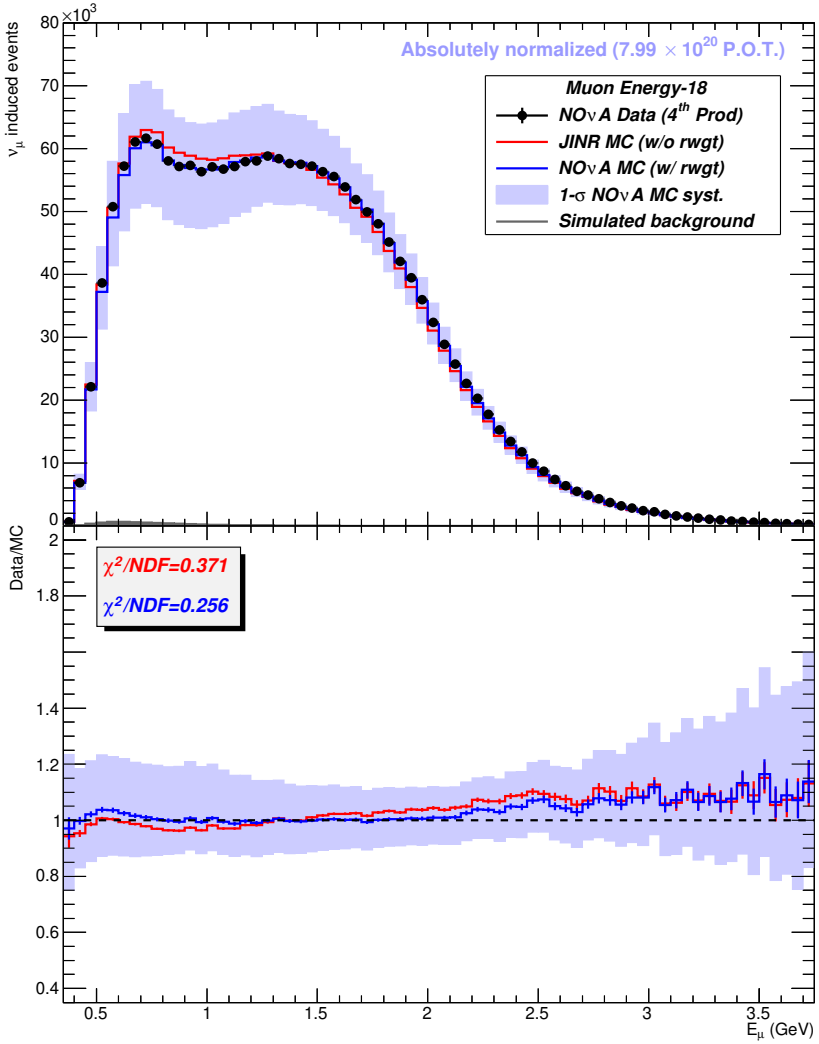
ND data comparison (FHC mode)

Muon energy

kNumuCutND2017Prod4



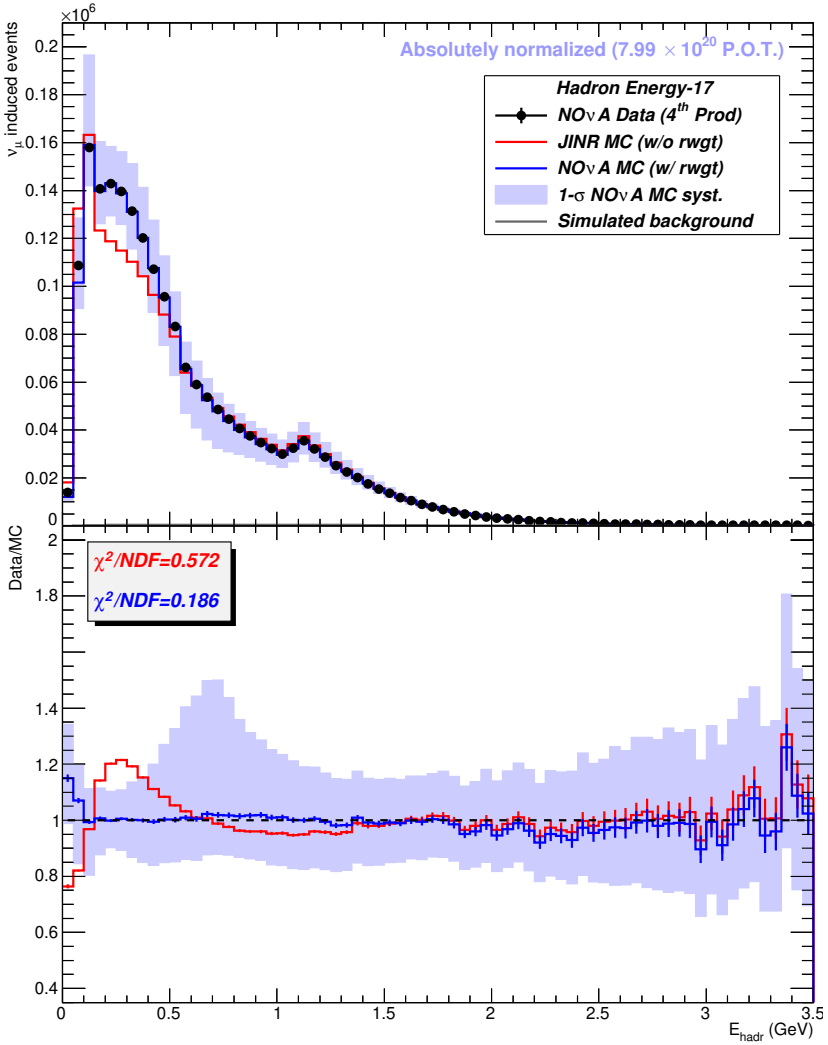
kNumuCutND2018



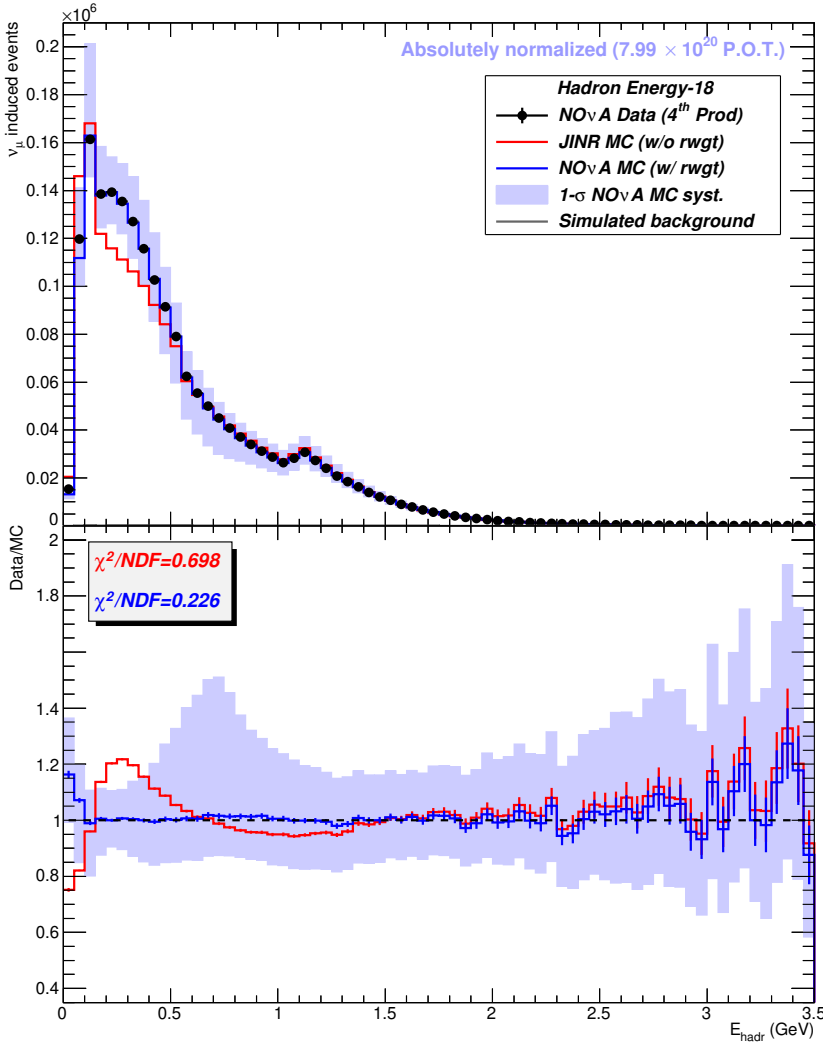
ND data comparison (FHC mode)

Hadron energy

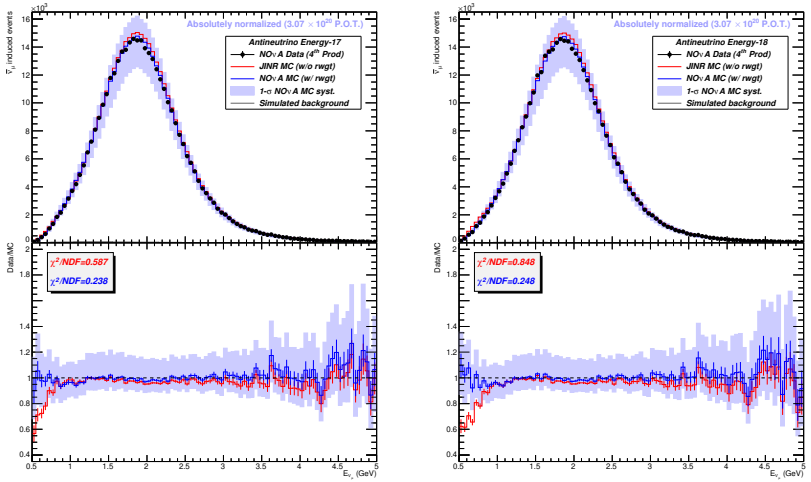
kNumuCutND2017Prod4



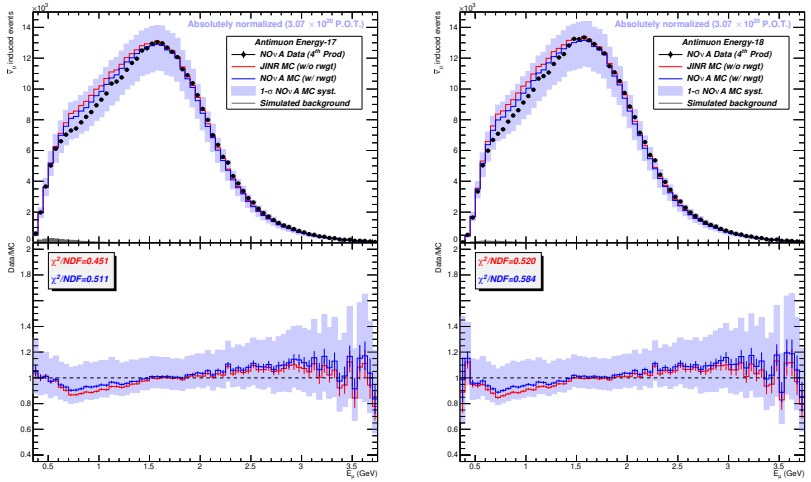
kNumuCutND2018



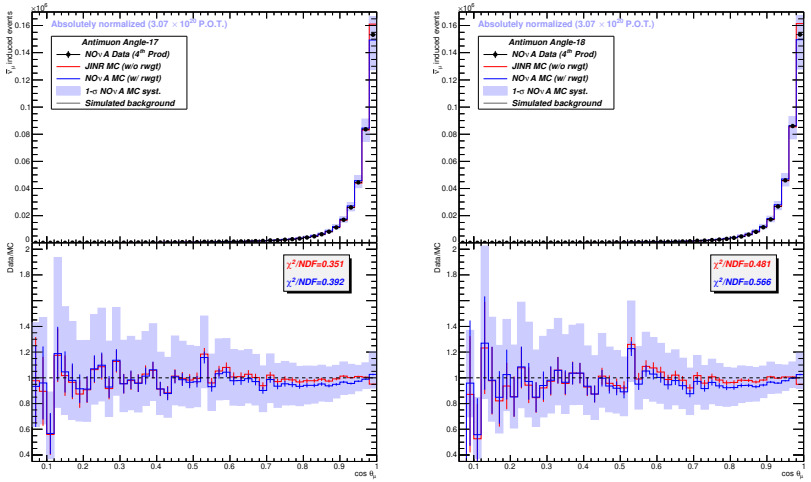
ND data comparison (RHC mode)



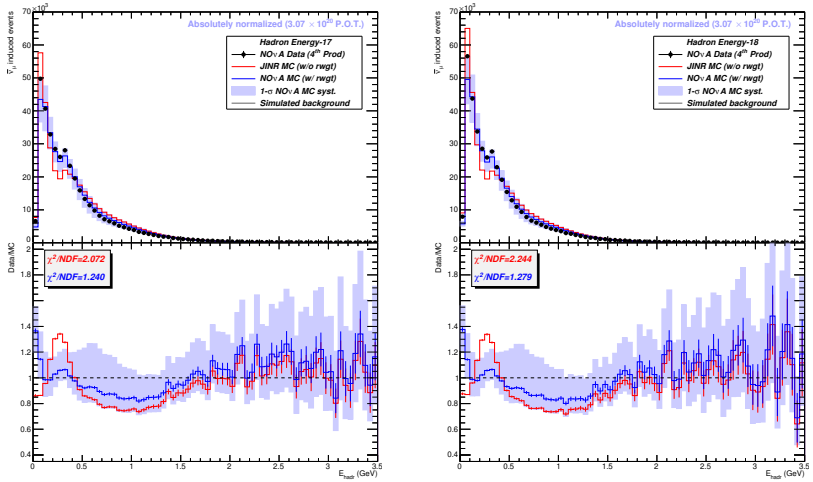
Antineutrino energy



Antimuon energy



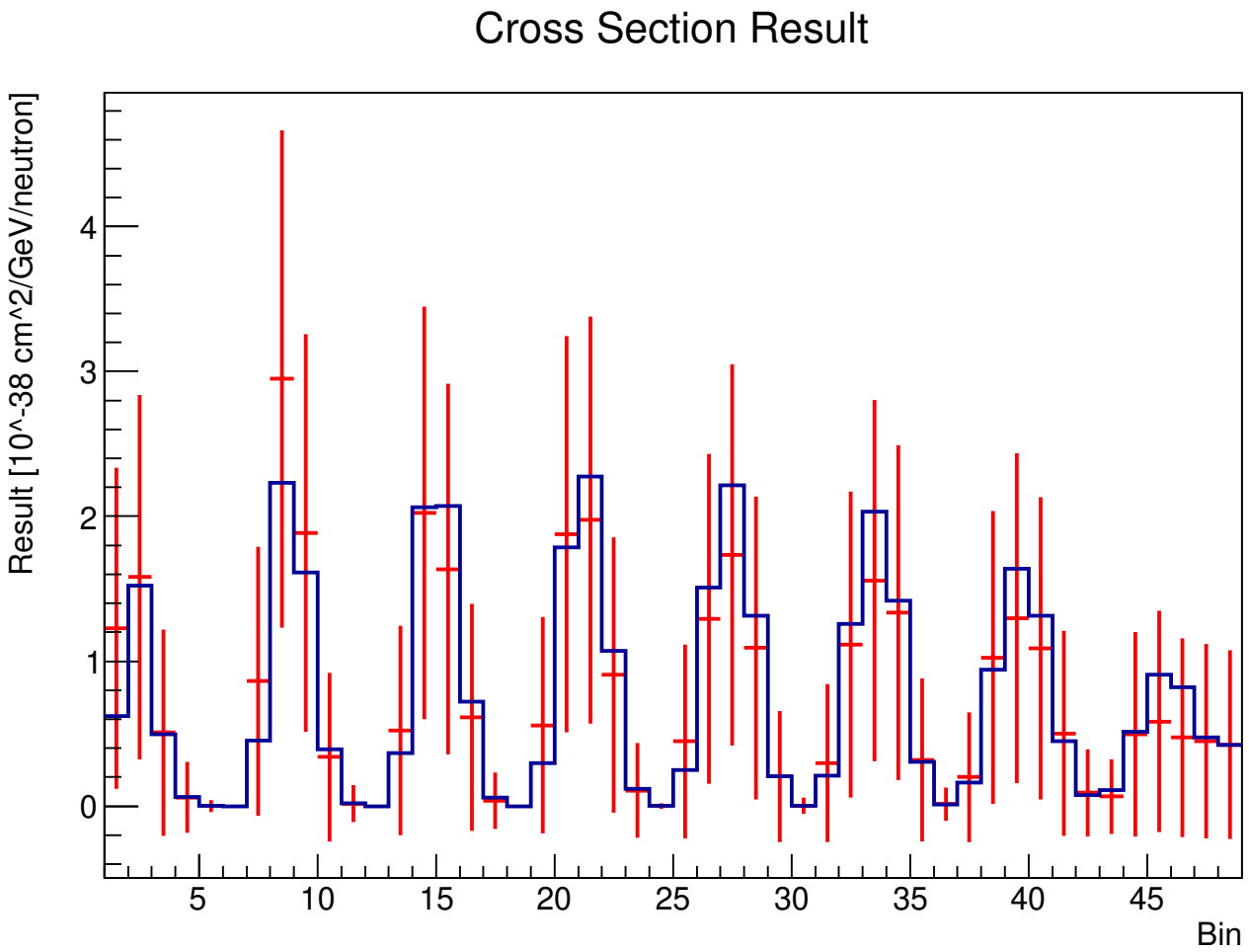
Cos of the muon angle



Hadron energy

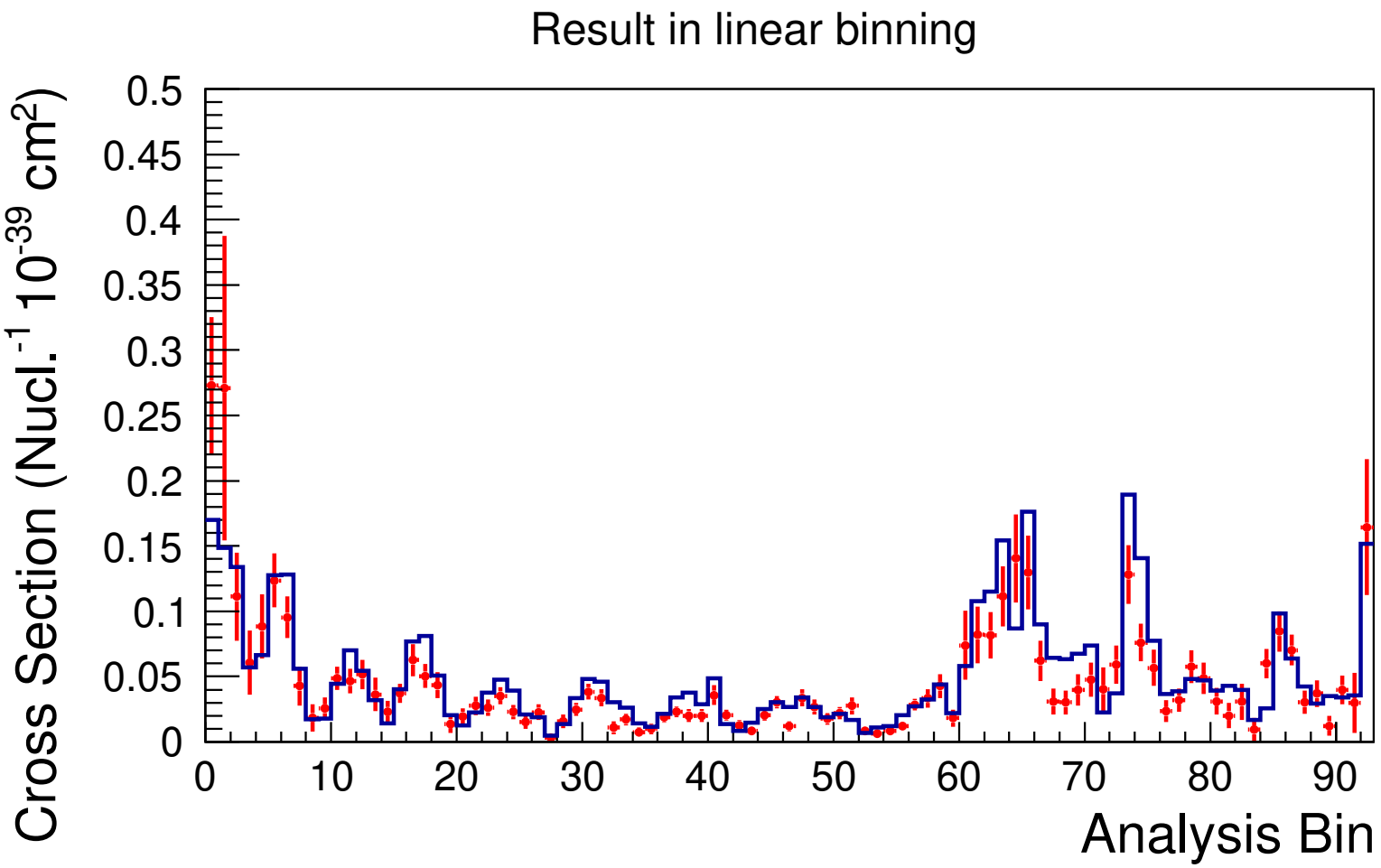
Many plots in Backup slides (E_ν, E_μ, $\cos\theta_\mu$, E_{had}, $|\vec{q}|$, Q^2, W)

Comparison with T2K data



Comparison with ν_μ CC cross sections on H_2O with 0π in the final state [PRD97(2018)012001].

Comparison with T2K data



Comparison with ν_μ CC cross sections on C_8H_8 with 0π in the final state [PRD98(2018)032003].

Future plans

JINR model could be used as an alternative way to estimate number of events and systematics in the detector. Also the model allows to avoid rebukes in the overfitting and vagueness of reweighting procedure.

Reweighting procedure has some drawbacks, namely:

- The weights are calculated for true kinematic variables, but applied to reconstructed ones. As we think, this may lead to a discrepancy between the data and MC in the low-energy region.
- The procedure is not very accurate, because of MC inaccuracy (especially at regions with low number of events), not too fine-grained fluxes, ignoring of the detector design, etc.

Hence we propose to perform miniproduction with the JINR model.

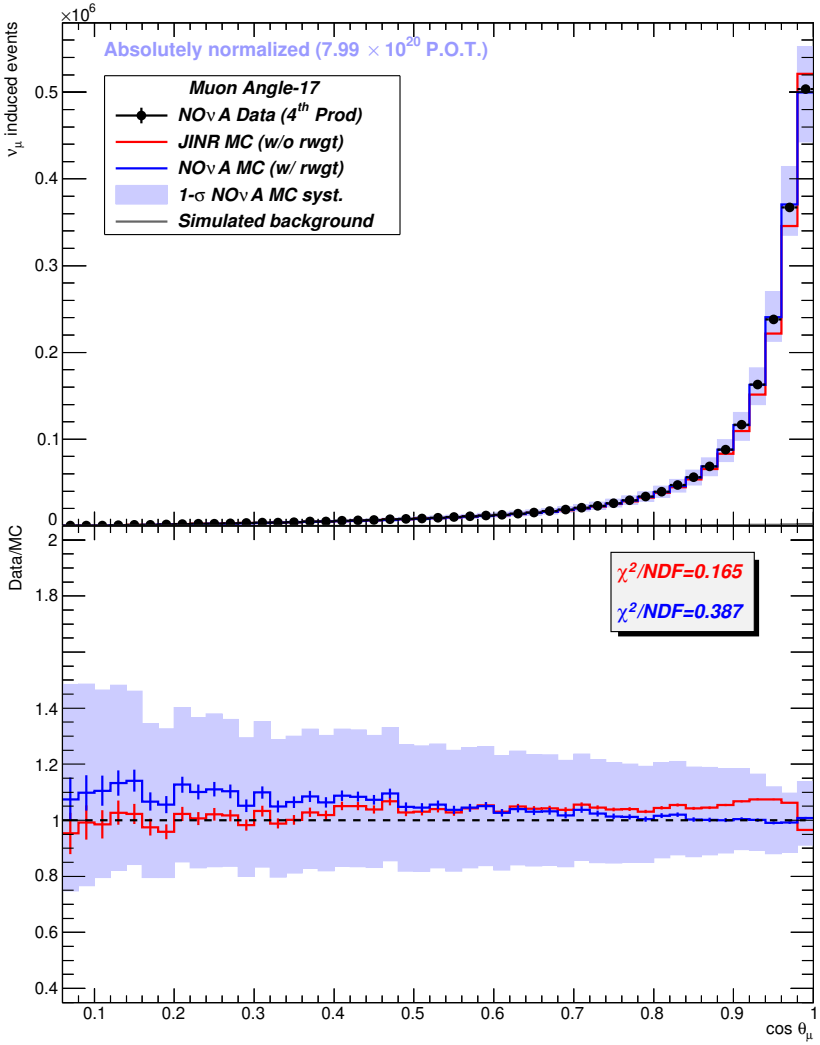
The validity of the JINR model was tested on the recent experiments MINERνA and T2K to measure $\nu_\mu(\bar{\nu}_\mu)$ CC cross sections with 0π in final state.

Backup

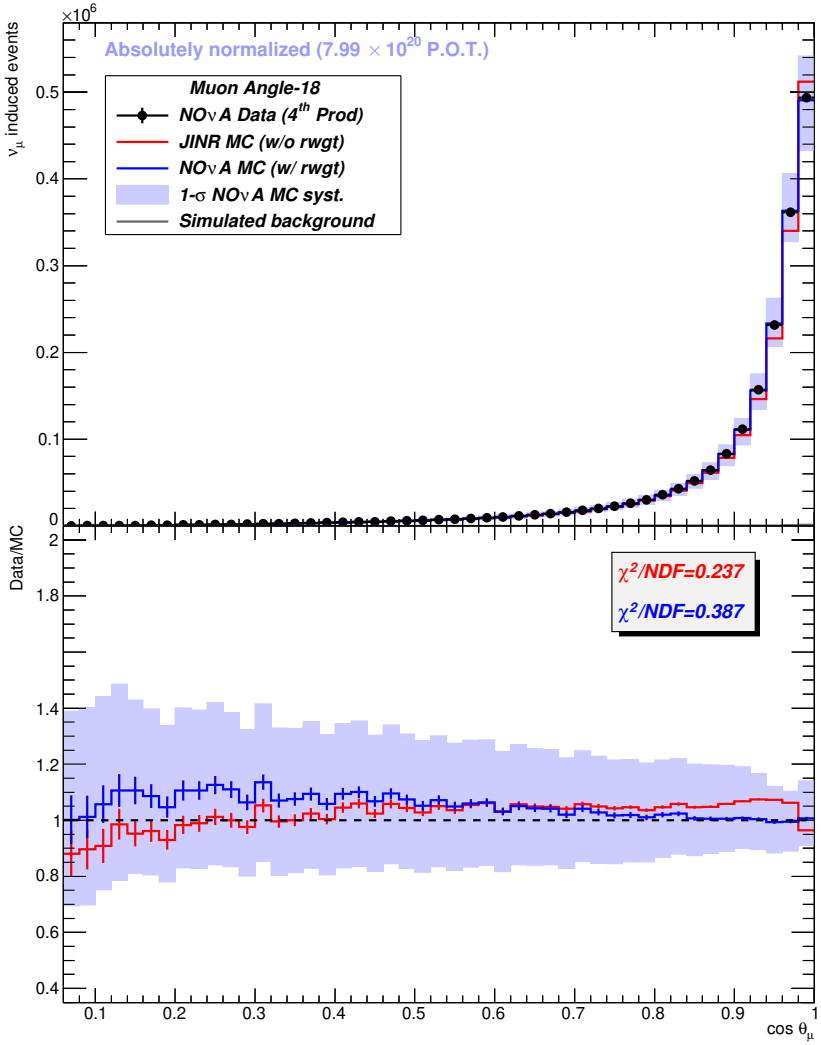
ND data comparison (FHC mode)

Cos of the muon angle

kNumuCutND2017Prod4



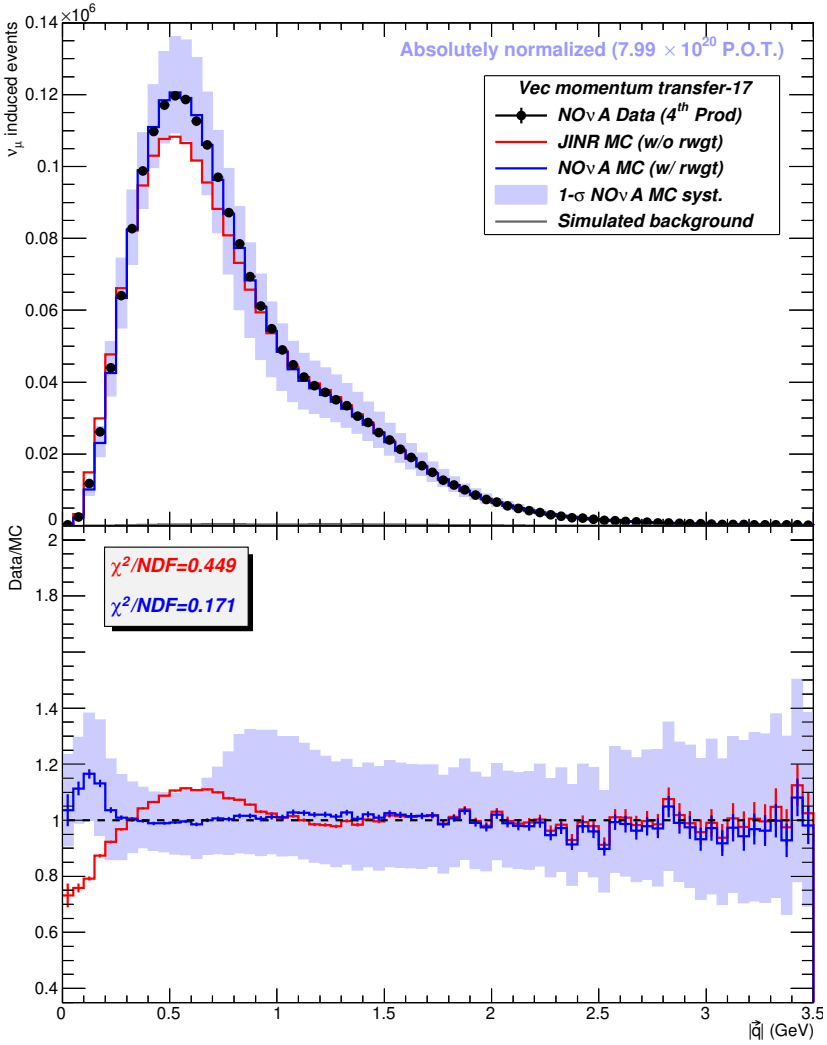
kNumuCutND2018



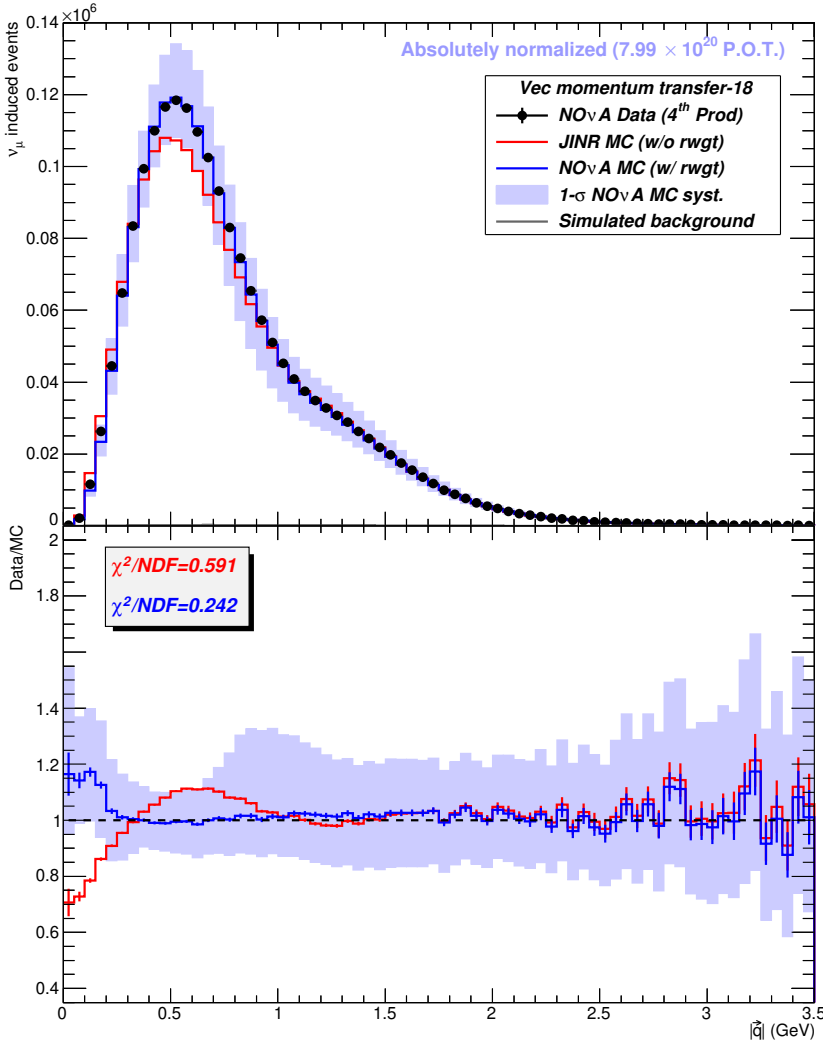
ND data comparison (FHC mode)

Module of vec momentum transfer

kNumuCutND2017Prod4



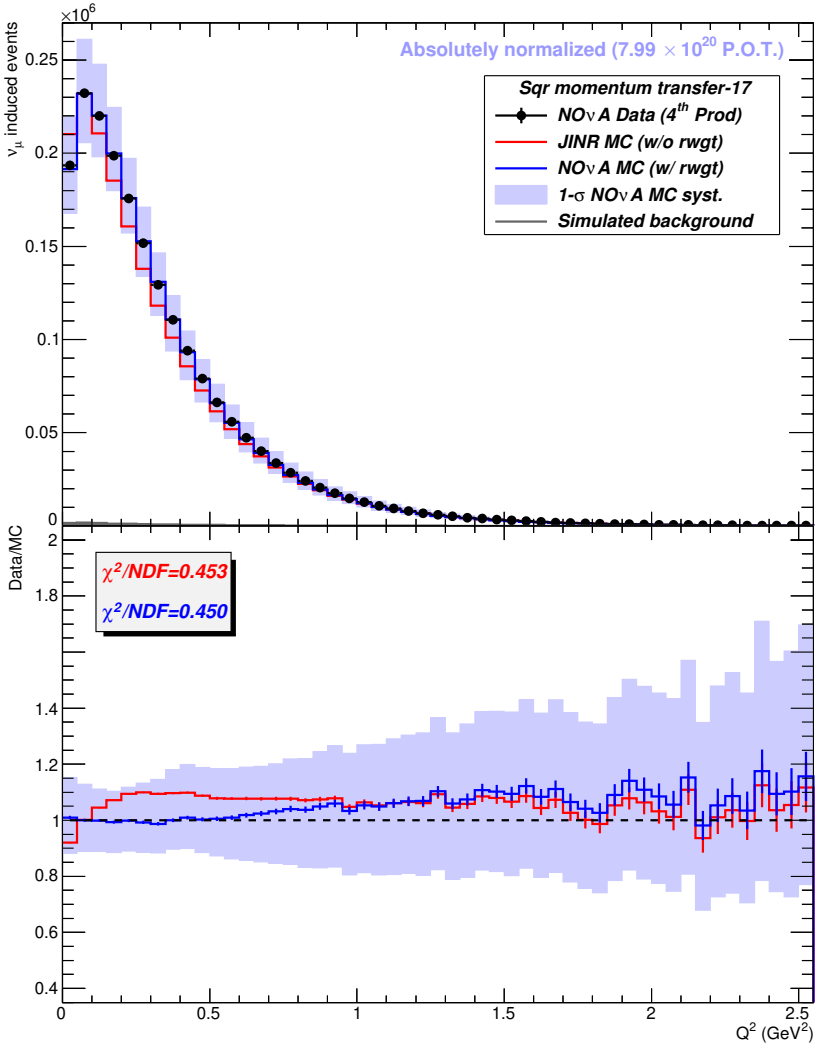
kNumuCutND2018



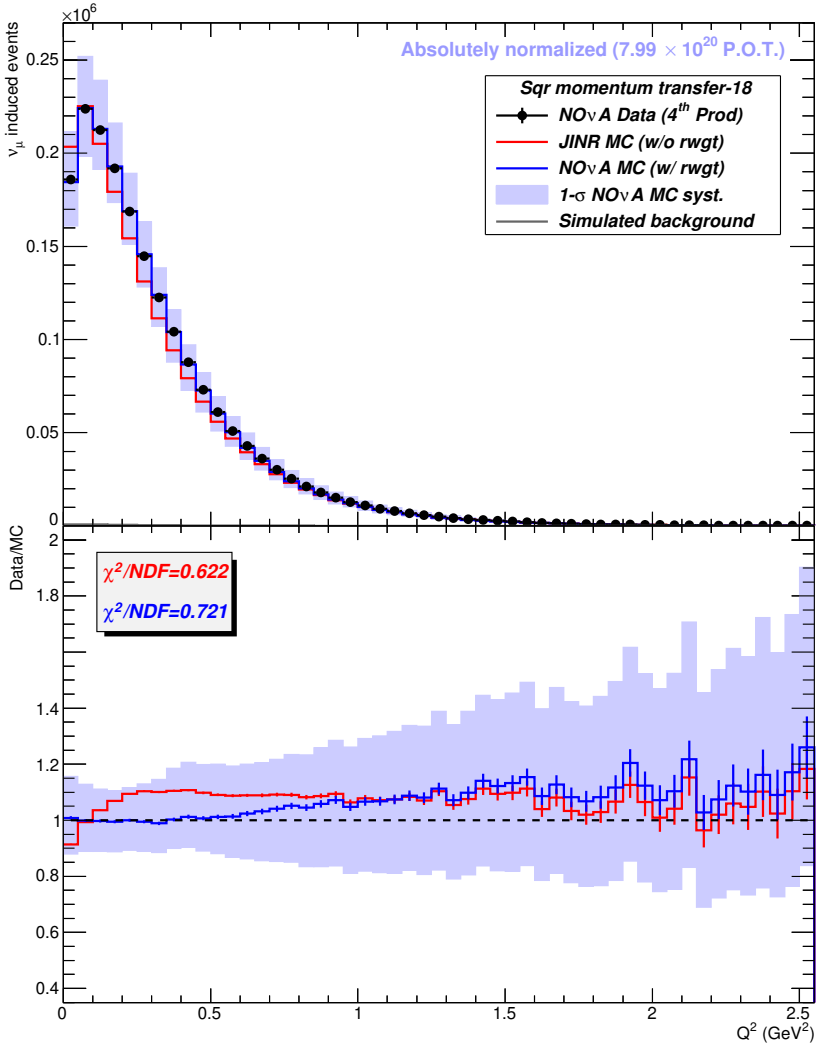
ND data comparison (FHC mode)

Square of momentum transfer

kNumuCutND2017Prod4



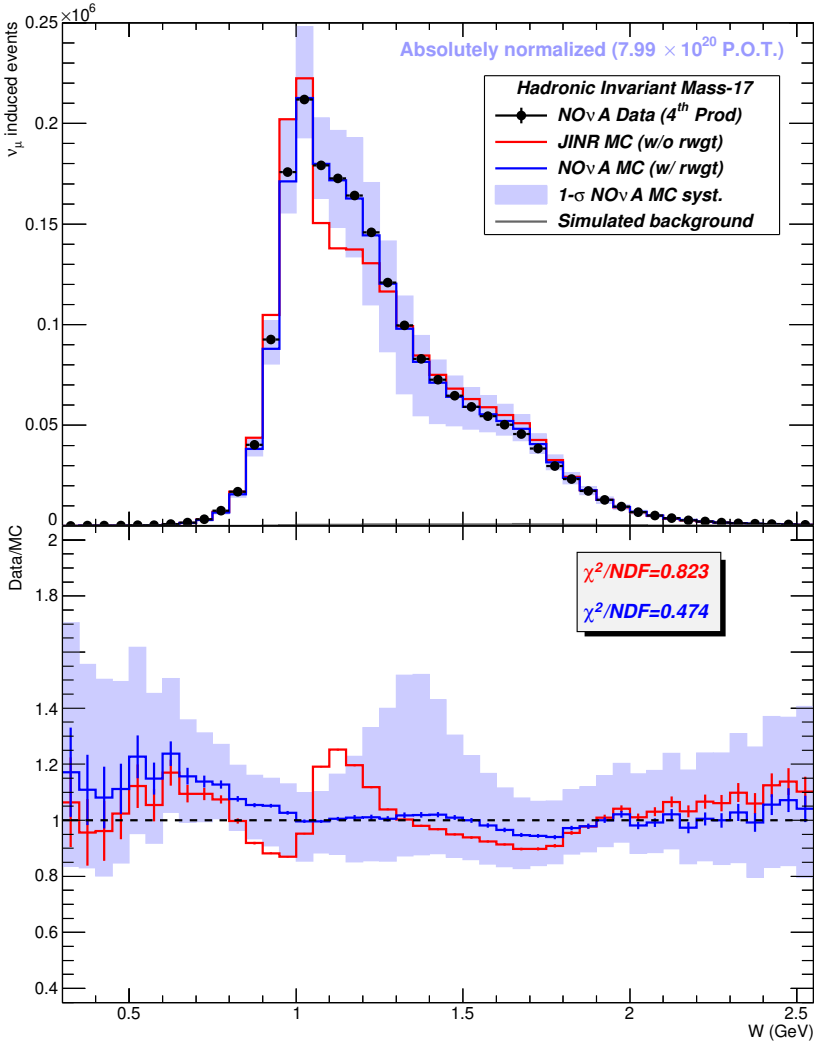
kNumuCutND2018



ND data comparison (FHC mode)

Invariant mass

kNumuCutND2017Prod4



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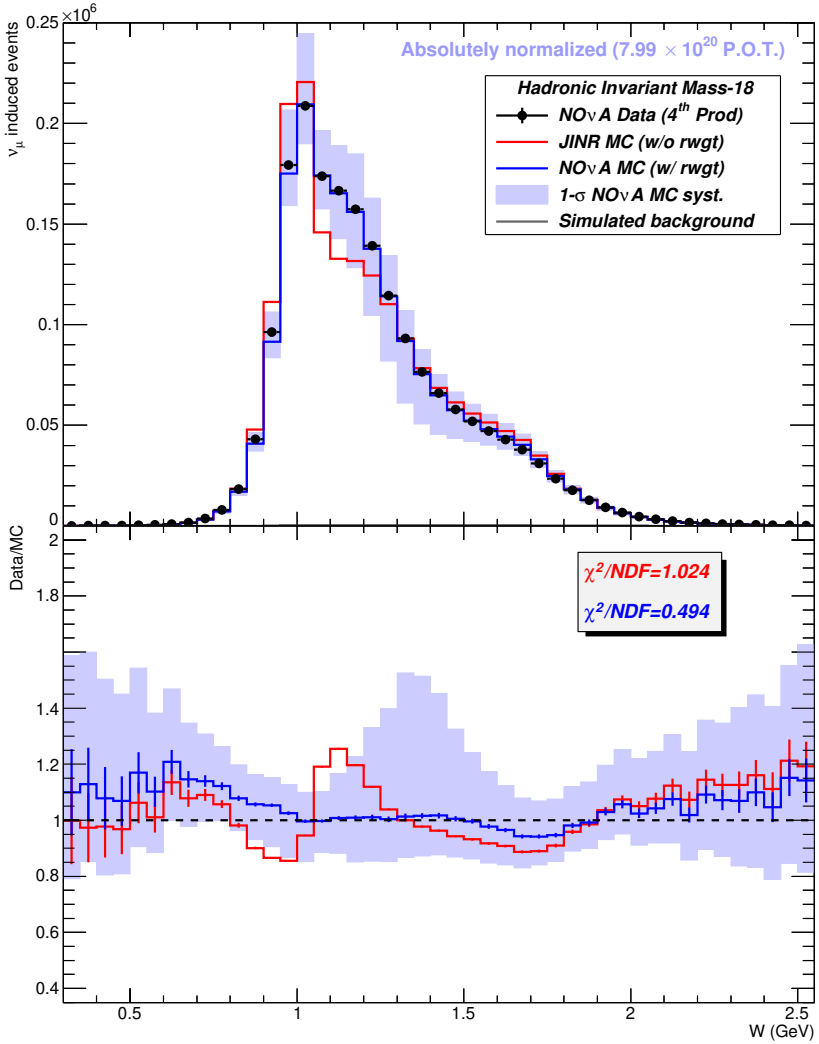

ND data comparison (RHC mode)

Antineutrino energy

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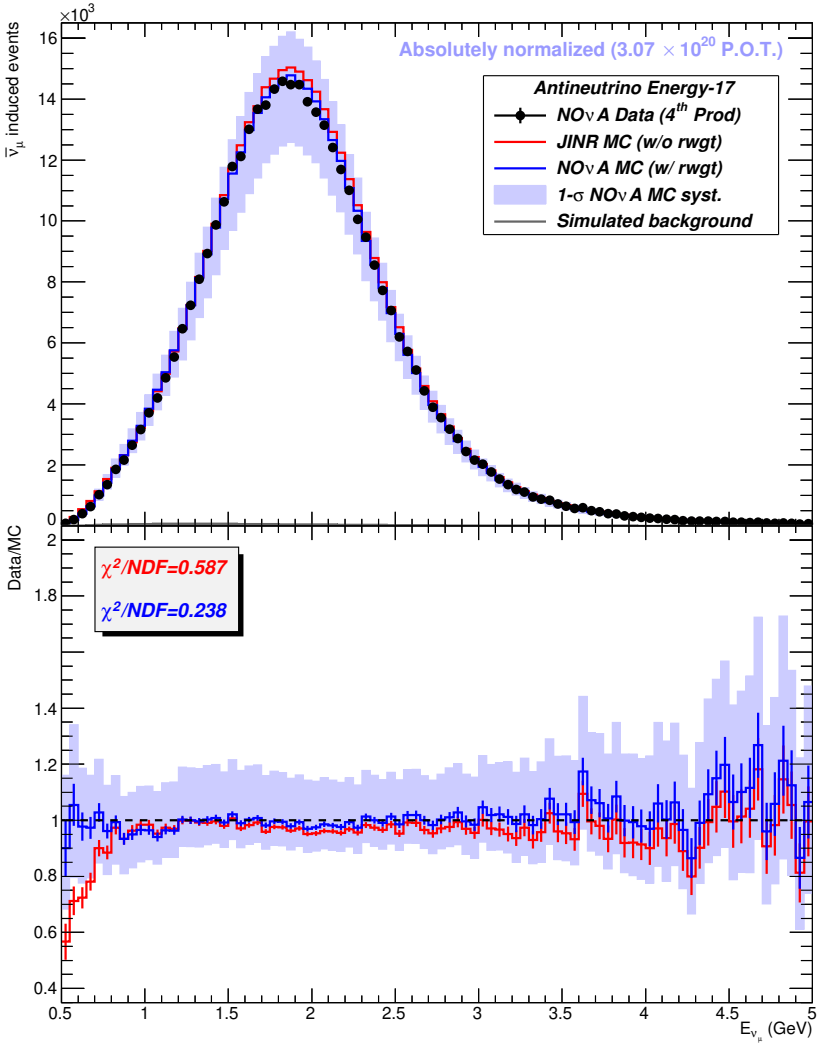

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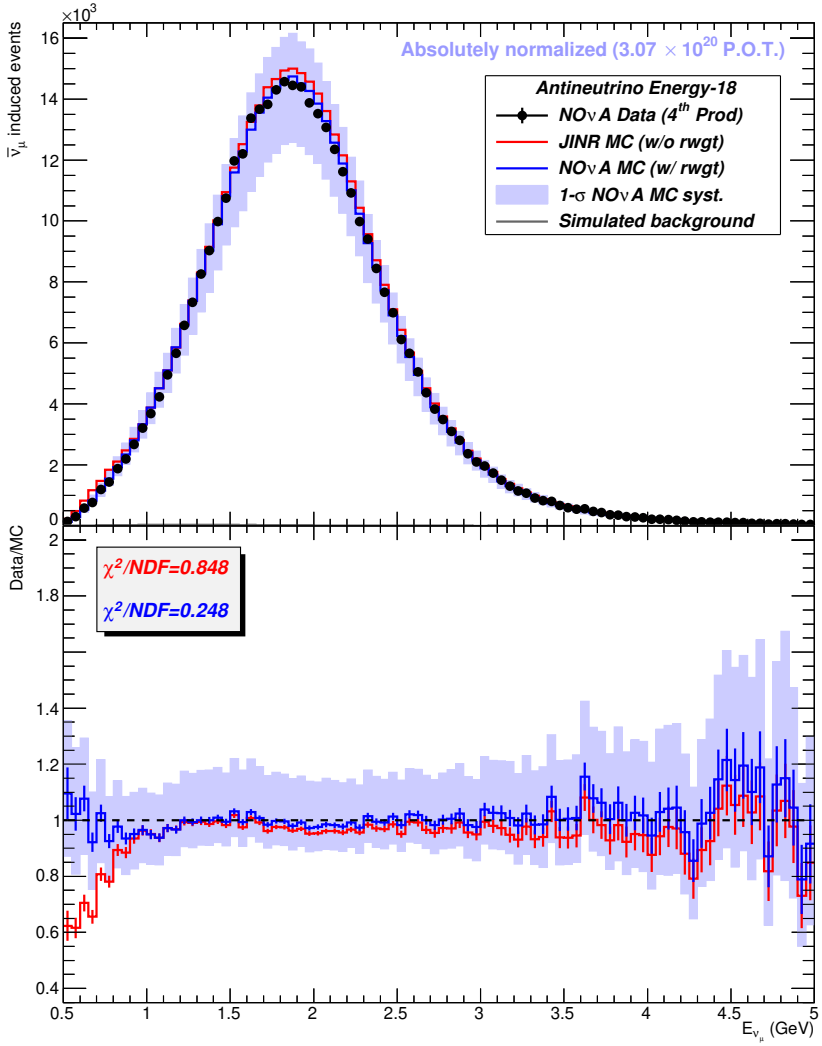

ND data comparison (RHC mode)

Antimuon energy

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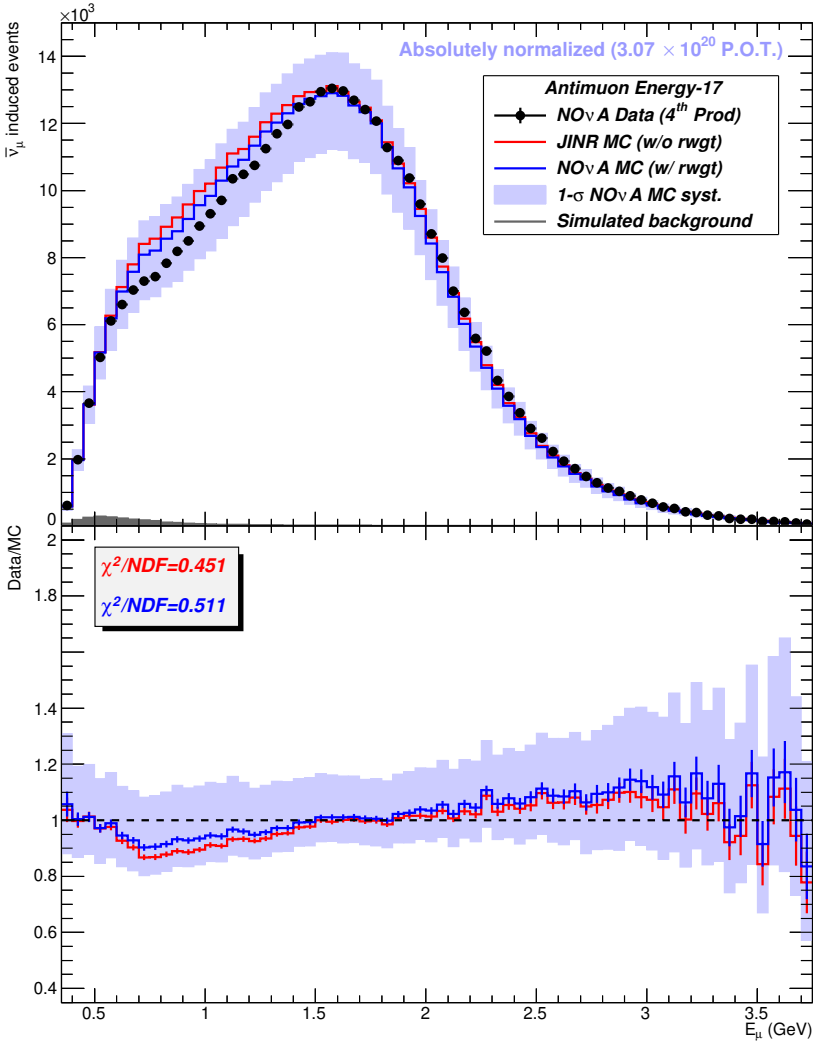

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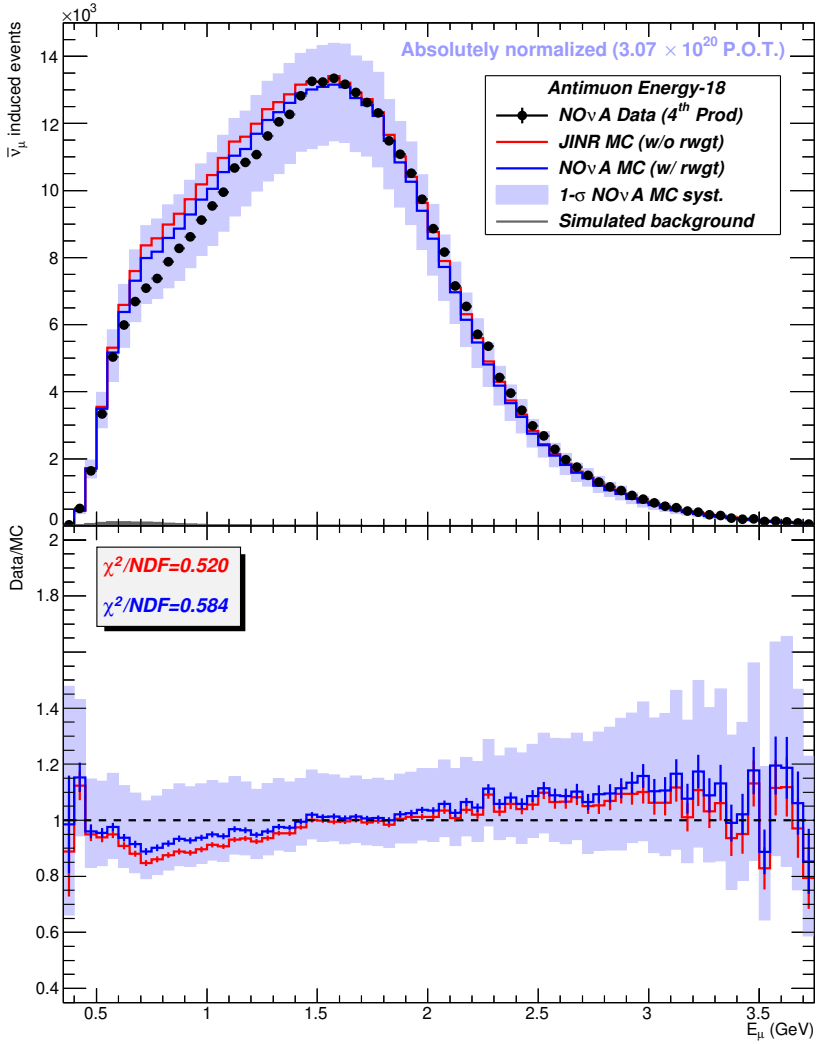

ND data comparison (RHC mode)

Cos of the muon angle

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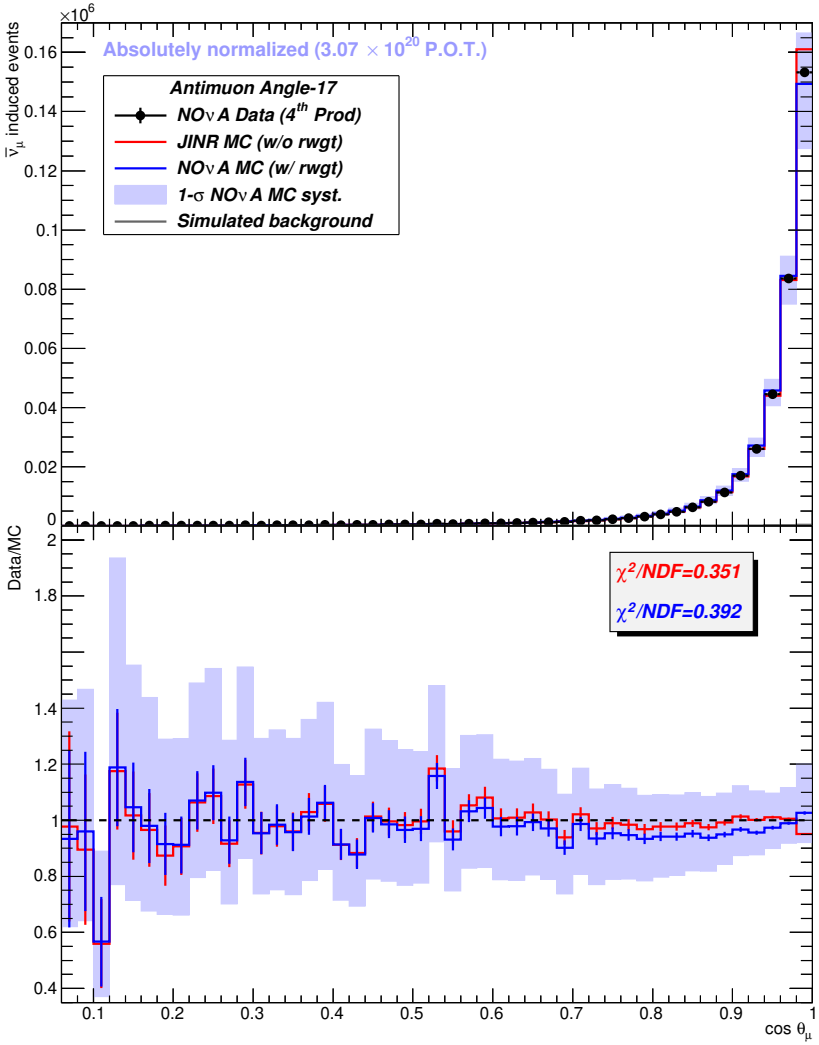

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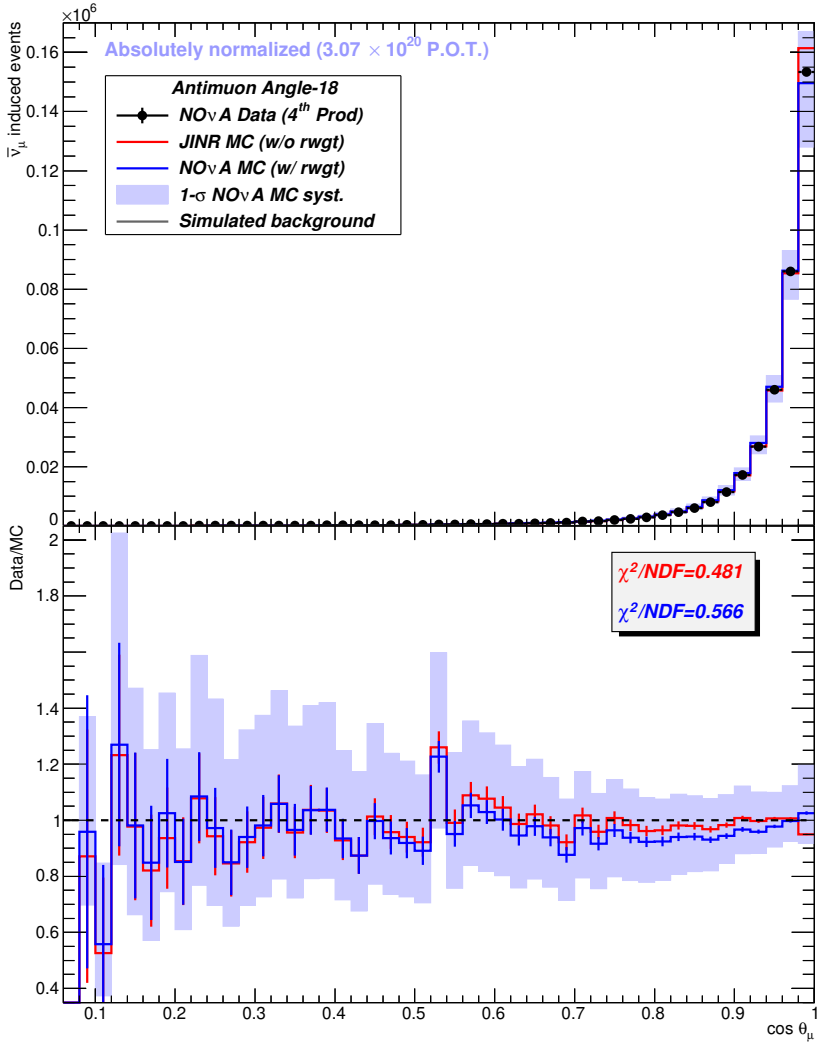

ND data comparison (RHC mode)

Hadron energy

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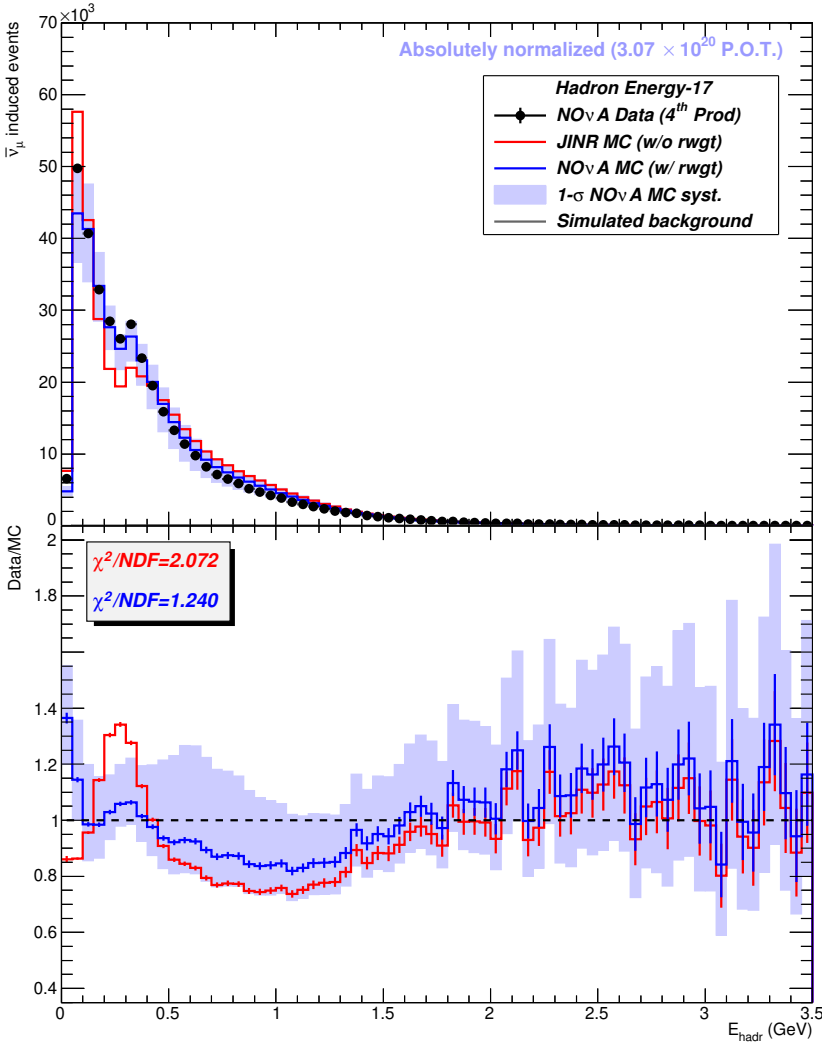
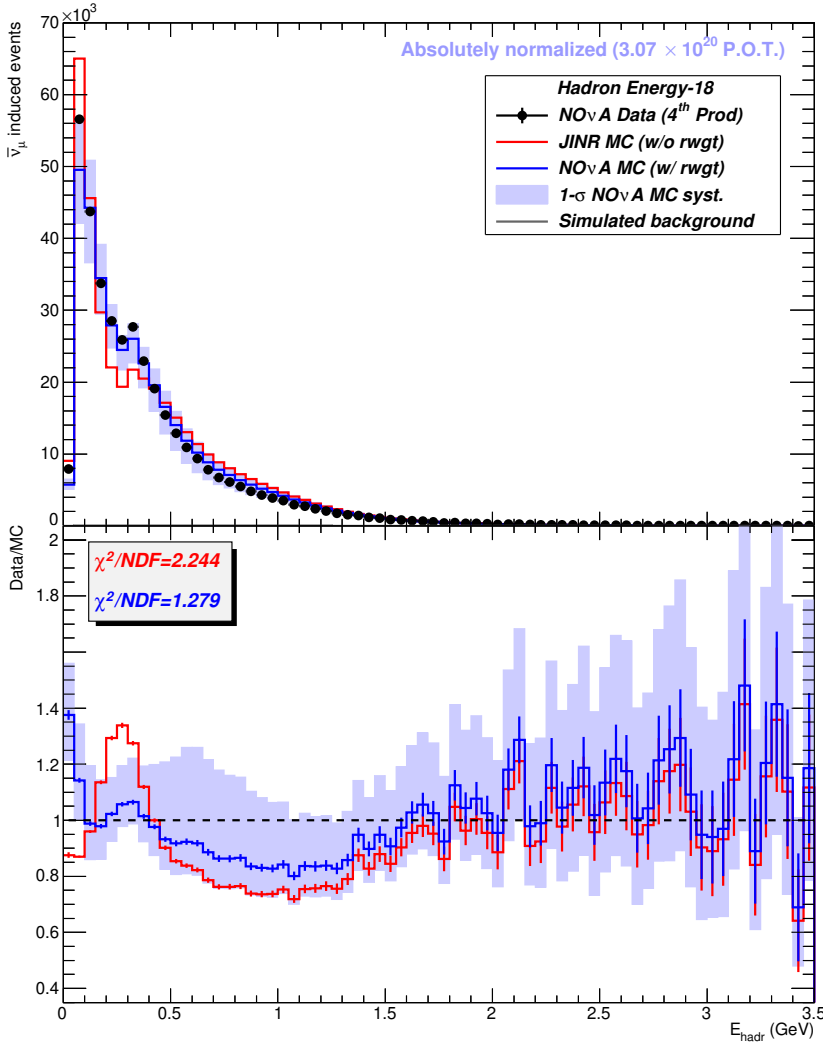


kNumuCutND2018



ND data comparison (RHC mode)

Module of vec momentum transfer

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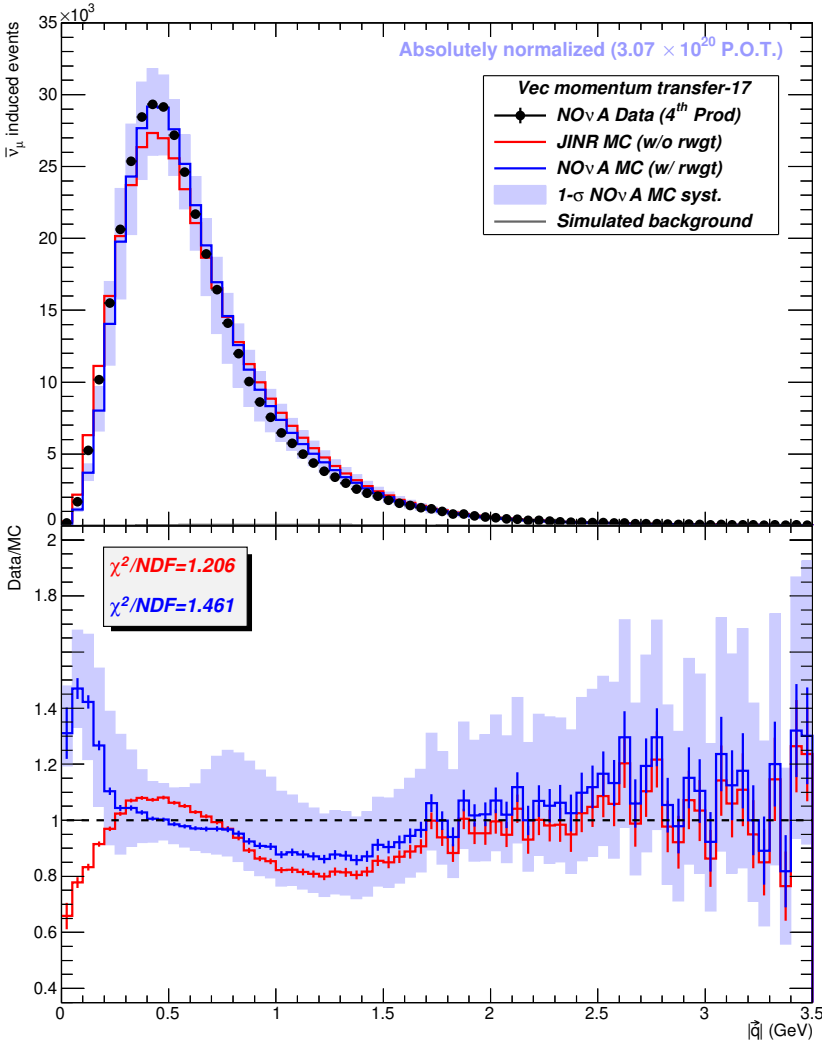

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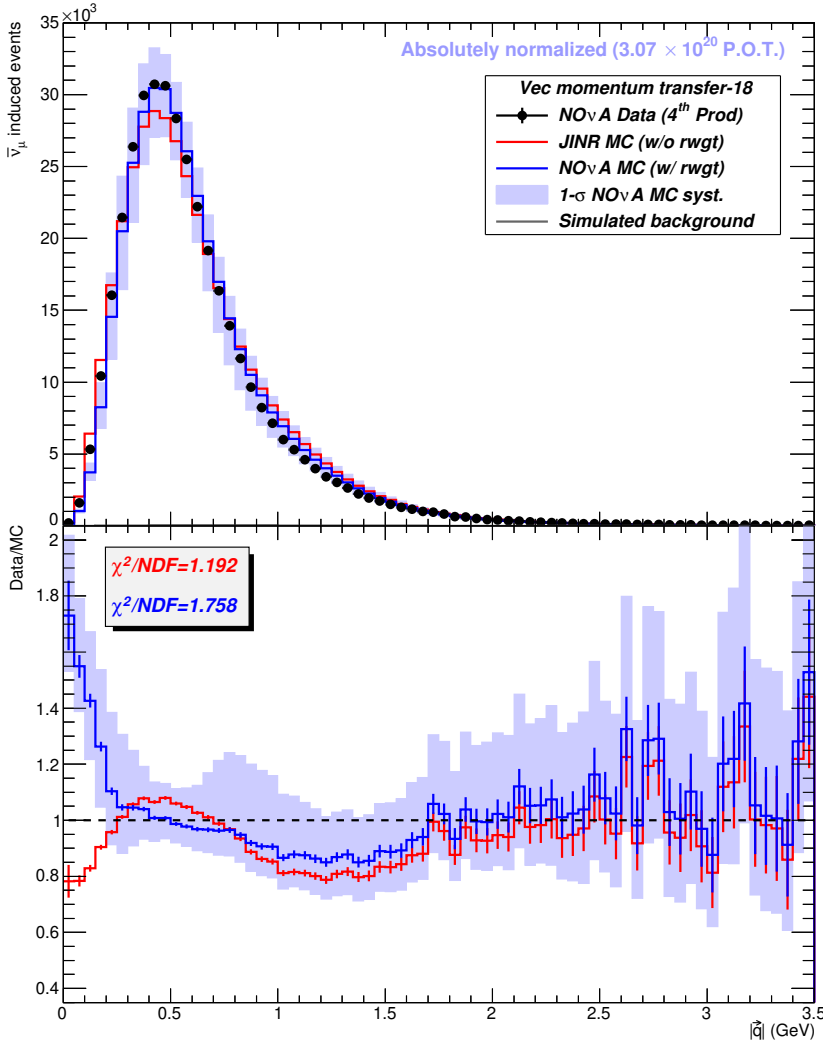

ND data comparison (RHC mode)

Square of momentum transfer

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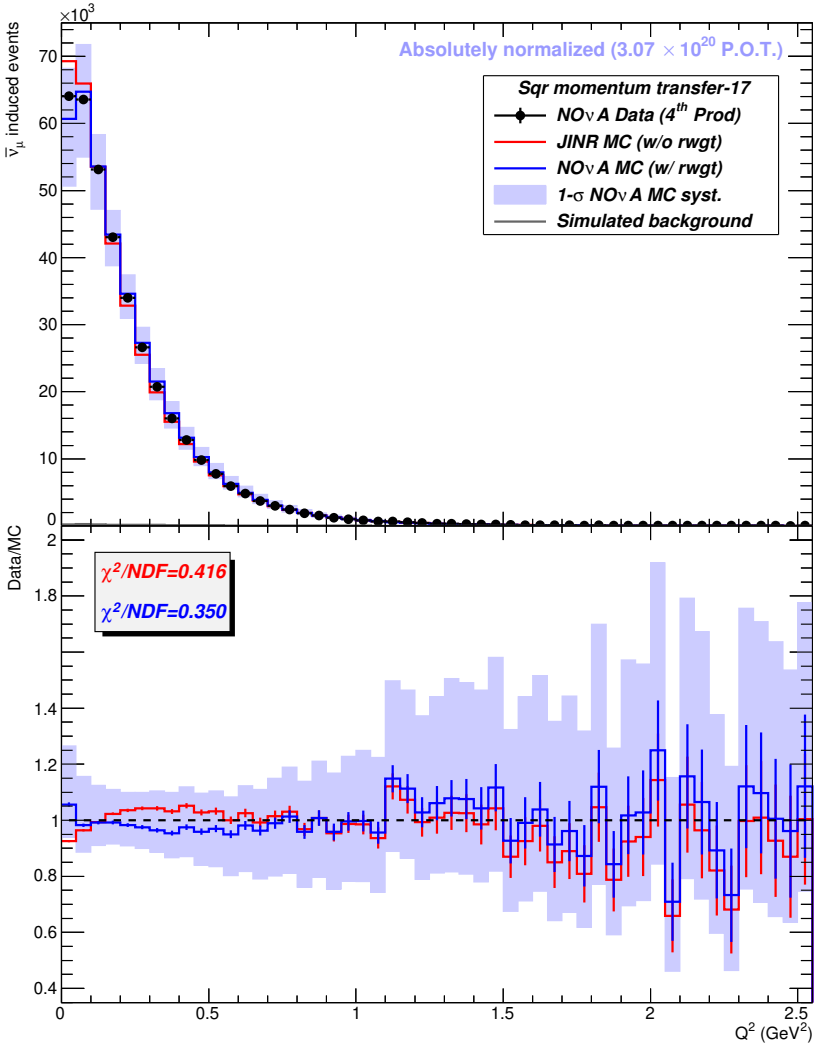

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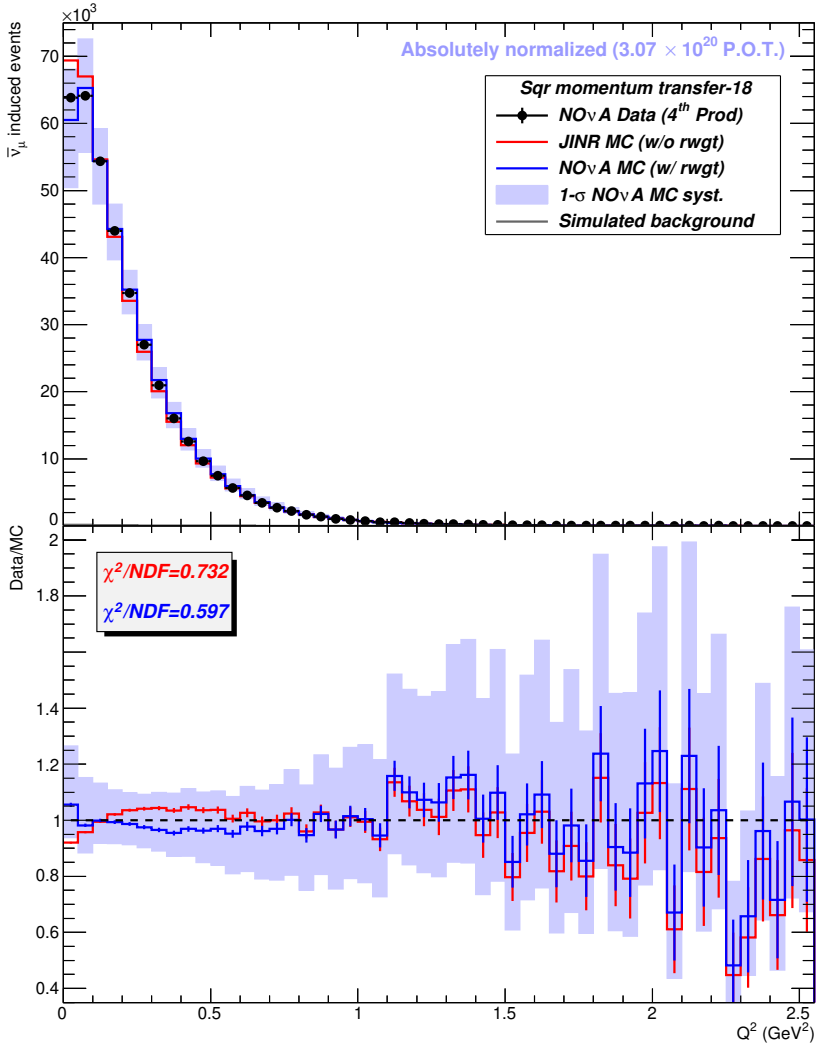

ND data comparison (RHC mode)

Invariant mass

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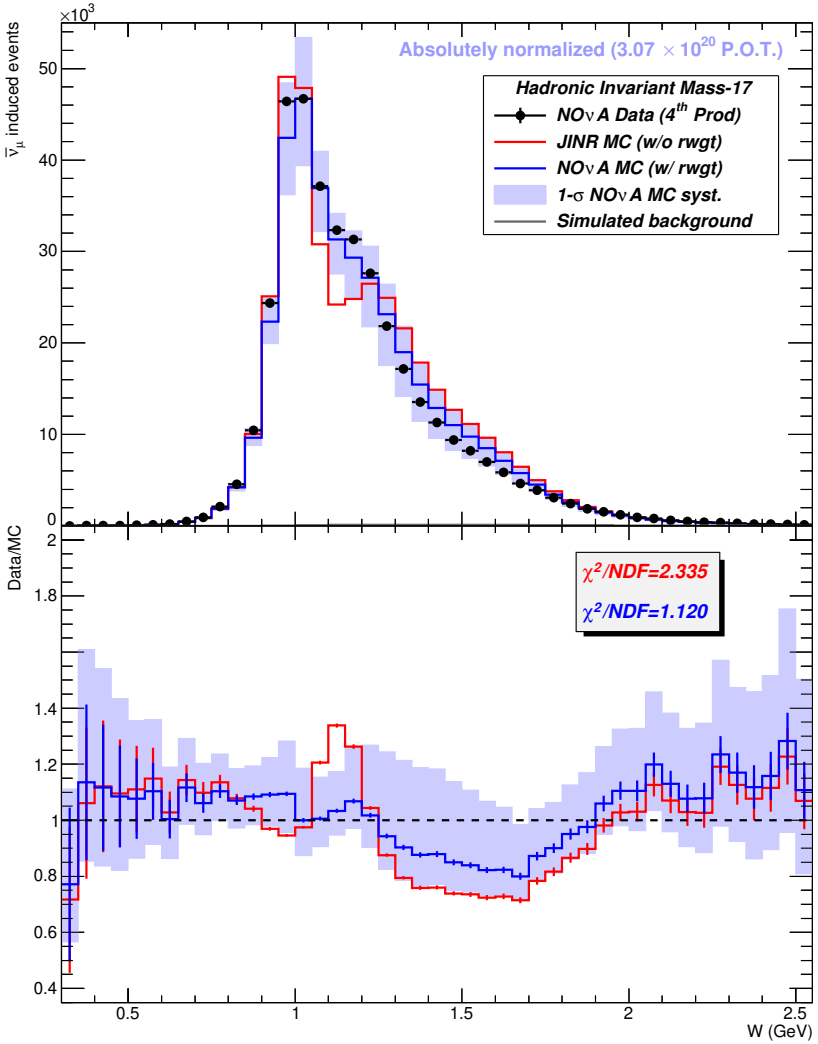

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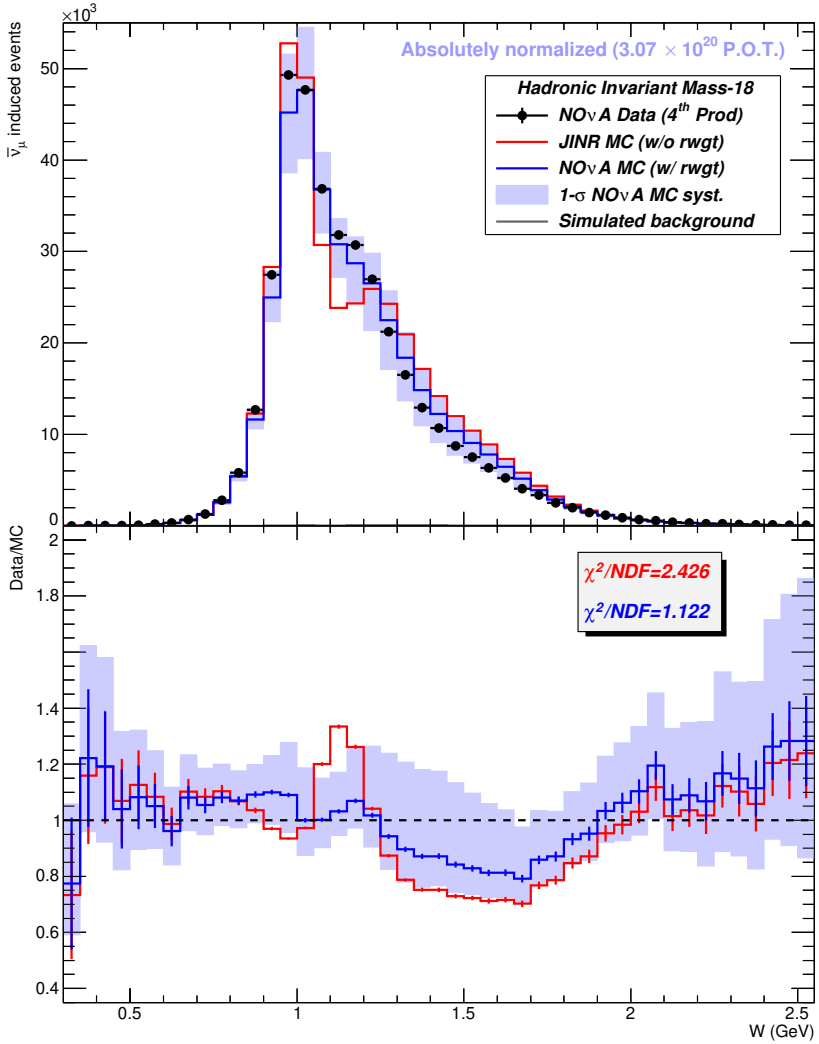
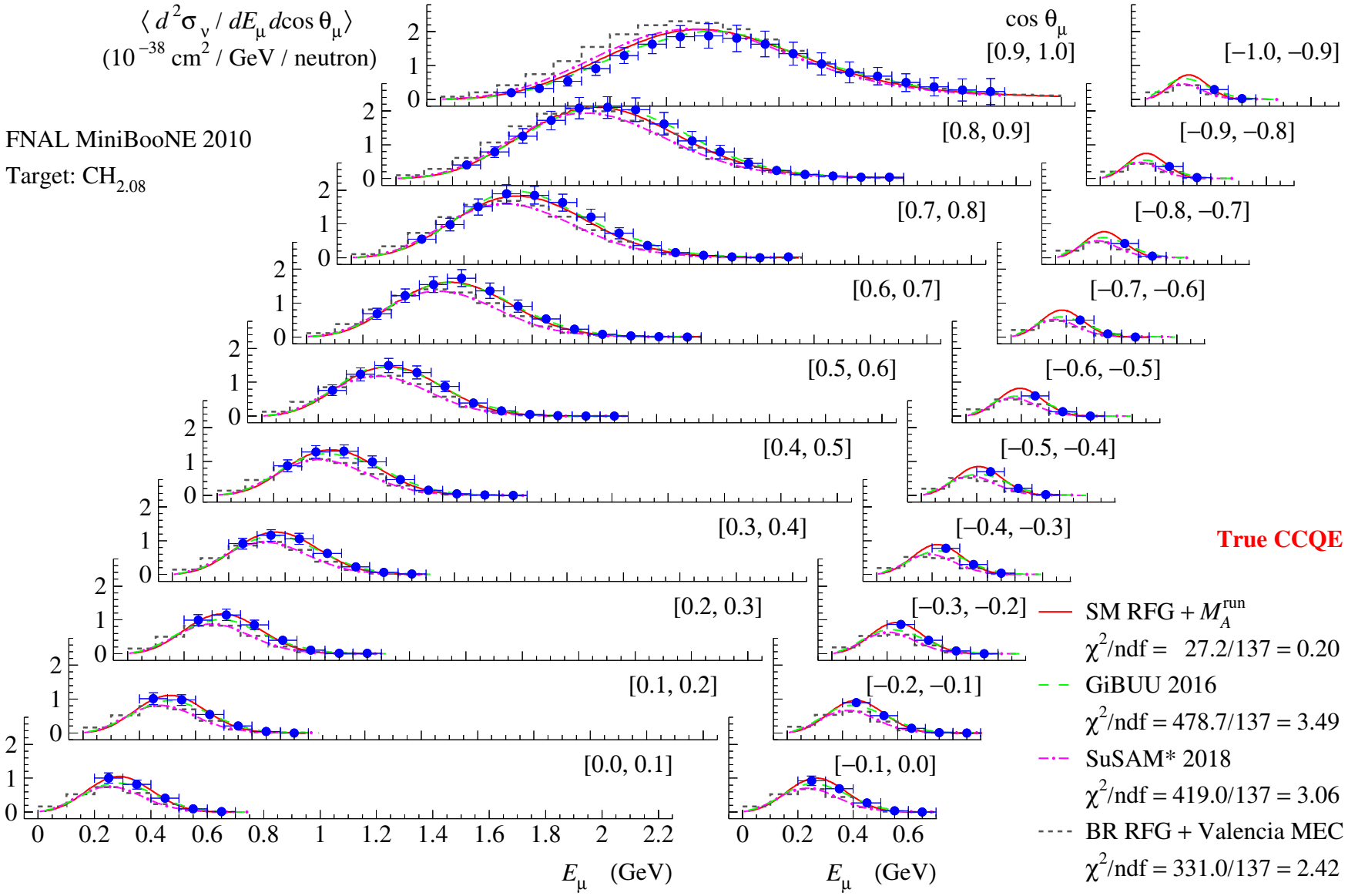
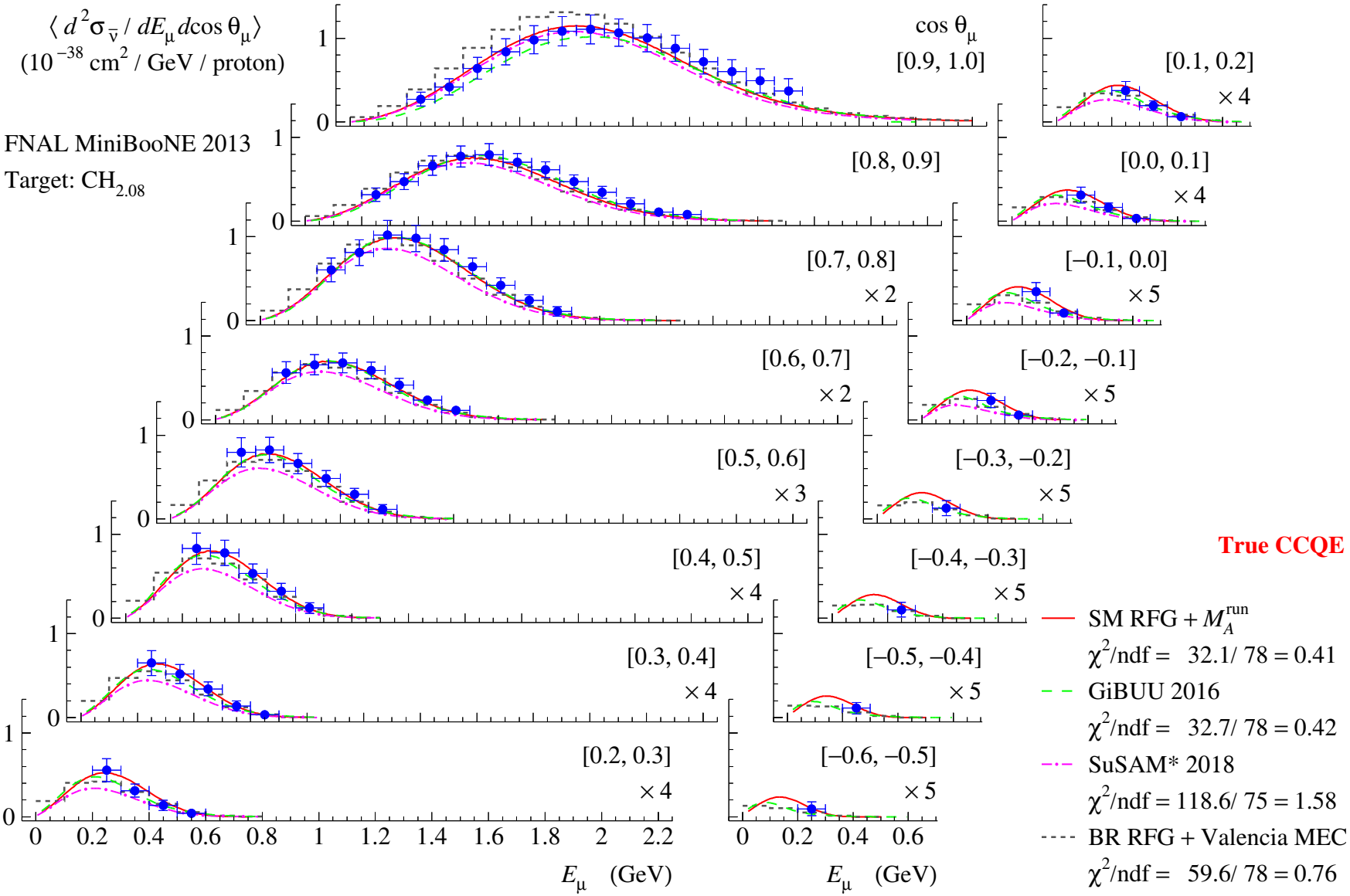


Comparison with MiniBooNE data



Comparison with MiniBooNE data



Comparison with MINERνA data