

# Fake data studies and the ND covariance

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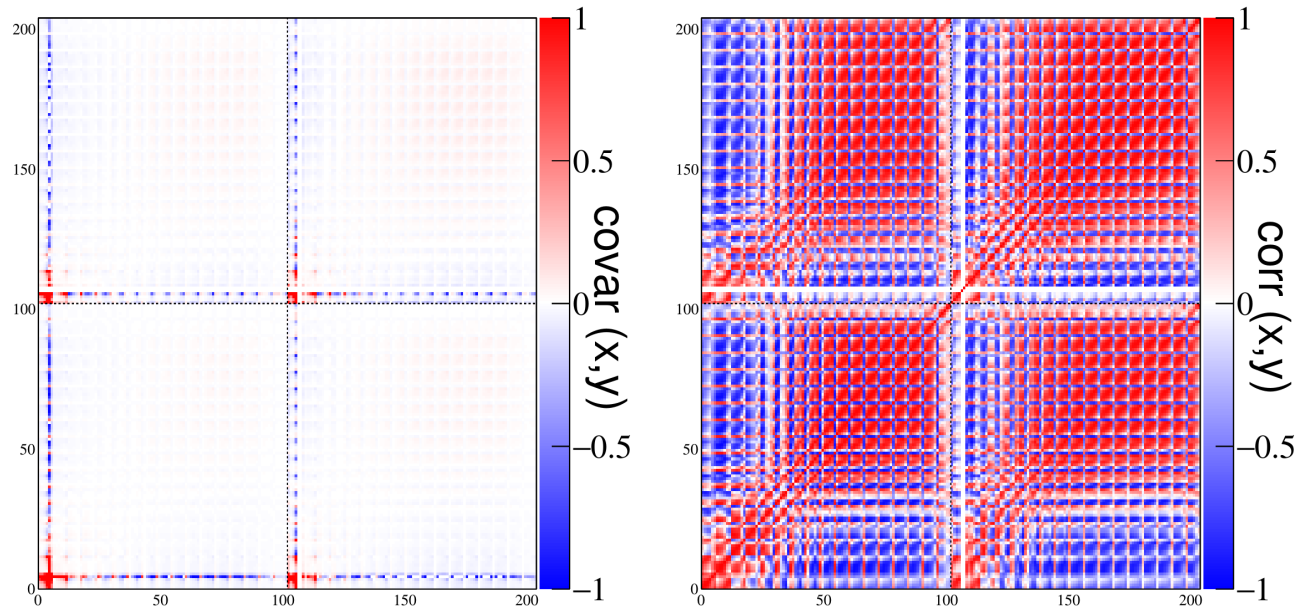
July 12, 2021



# Background

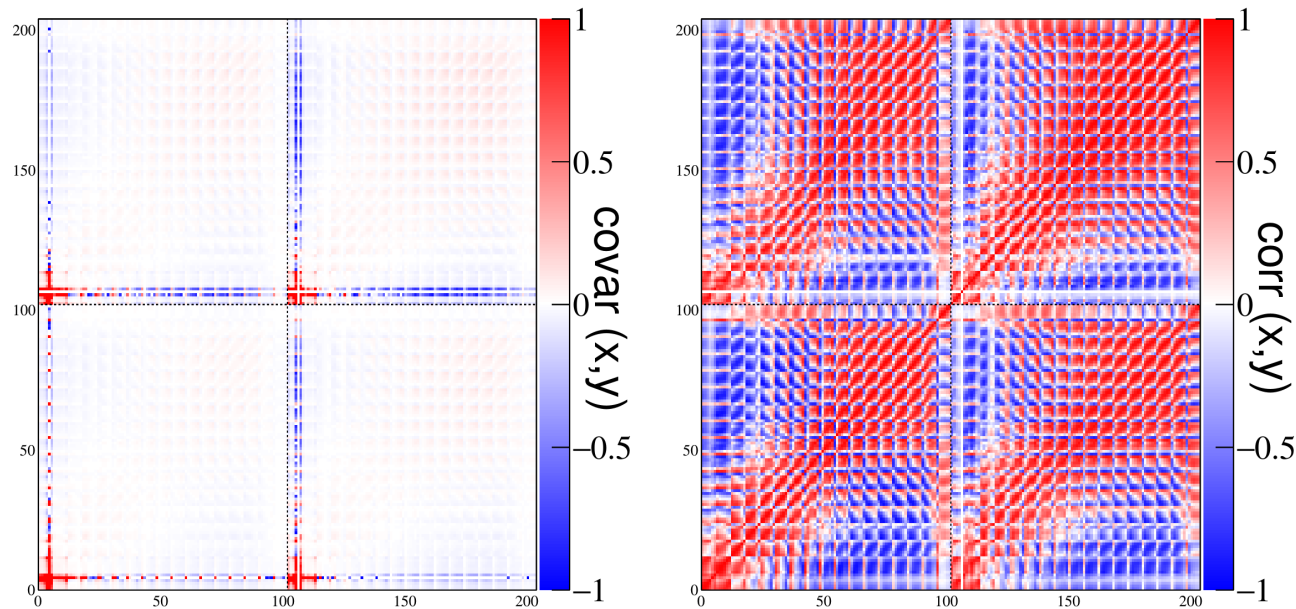
- ▶ TDR-era ND+FD fake data studies didn't really get very far because we always got huge  $\chi^2_{\min}$  values (e.g., 5–10k/ $\sim$ 200 bins)
- ▶ We put this down to the huge statistics at the near detector, and an insufficient detector/cross section systematic model
- ▶ But, playing with the ND detector systematic biases, Chris M and I found that the penalty from the ND detector covariance penalty term was larger than expected, odd because the variations should have been included in the ND covariance
- ▶ As a reminder, the nominal ND detector covariance is produced by looking at 500 random Gaussian throws of all the detector systematics in ND analysis bins

# How many throws is enough?



- ▶ Maybe there's no good answer to this, but Chris and I got worried that we didn't have enough throws in the ND covariance, so we made some tests
- ▶ The nominal matrix uses 500 systematic throws and 5 million FHC and RHC events
- ▶ Here, the nominal covariance and correlation matrices are shown

# How many throws is enough?



- ▶ Maybe there's no good answer to this, but Chris and I got worried that we didn't have enough throws in the ND covariance, so we made some tests
- ▶ Here the matrices used 10 million FHC and 10 million RHC simulated events and 1 million throws are used.
- ▶ Note the large difference between the two! The difference between 200k and 1m is very small, so I decided 1m is enough

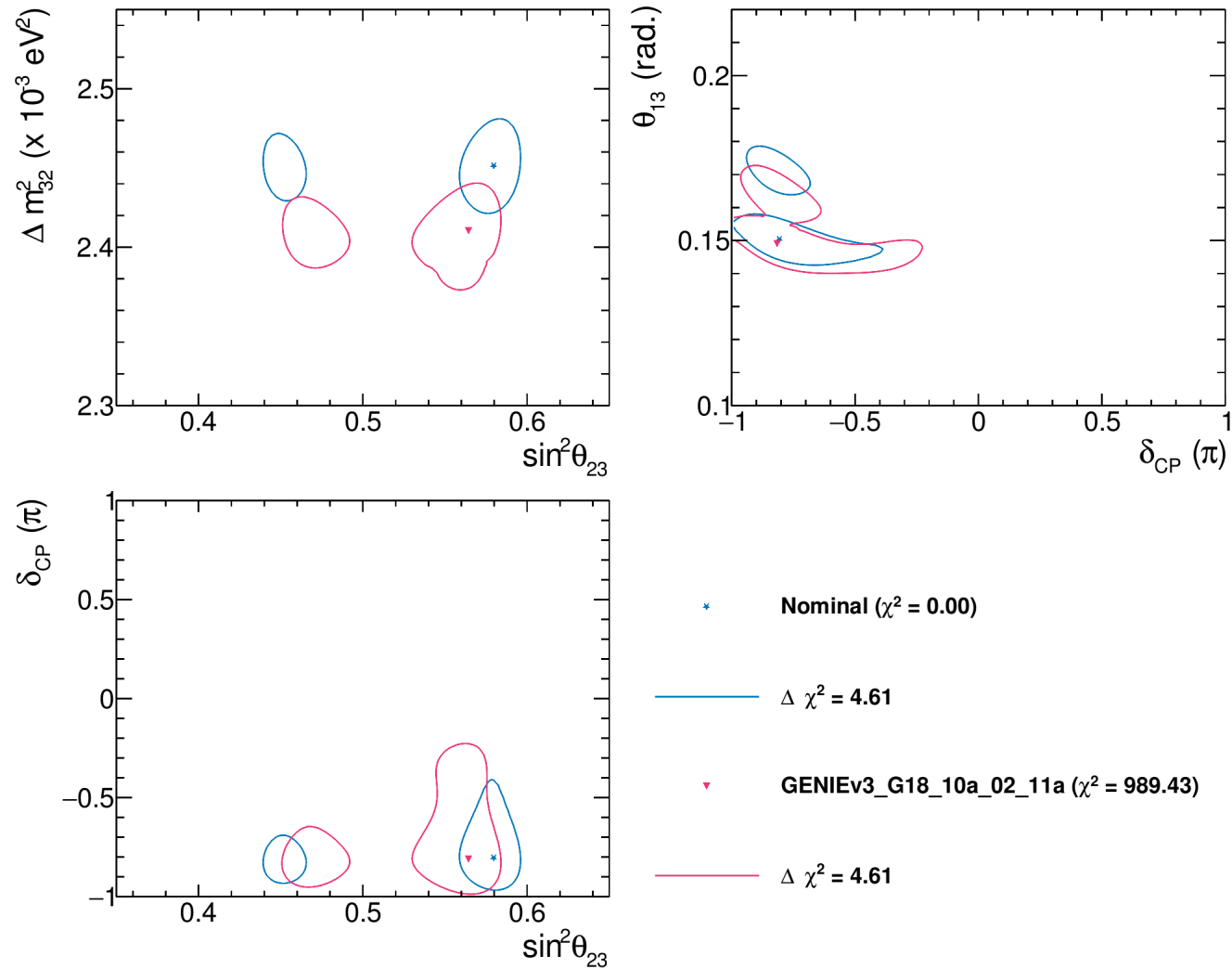
## Does this affect the main analysis?

- ▶ We were obviously pretty worried about this, particularly with the low exposure paper in ARC review.
- ▶ I ran a large fraction  $\sim 1/3$  of the throws (including FC) used in the paper and all Asimovs with the new ND covariance, and didn't observe any differences:
  - ▶ FC critical  $\Delta\chi^2$  values were within the expected statistical uncertainties
  - ▶ Asimovs were on top of the old ones
  - ▶ Fraction of throws above threshold are not visibly different
- ▶ Conclude that this is (very fortunately) not an issue for small excursions from the nominal systematic parameter values, which is really what we use in the regular sensitivity studies. Probably also mitigated by always taking the difference between two fits for the same throw.

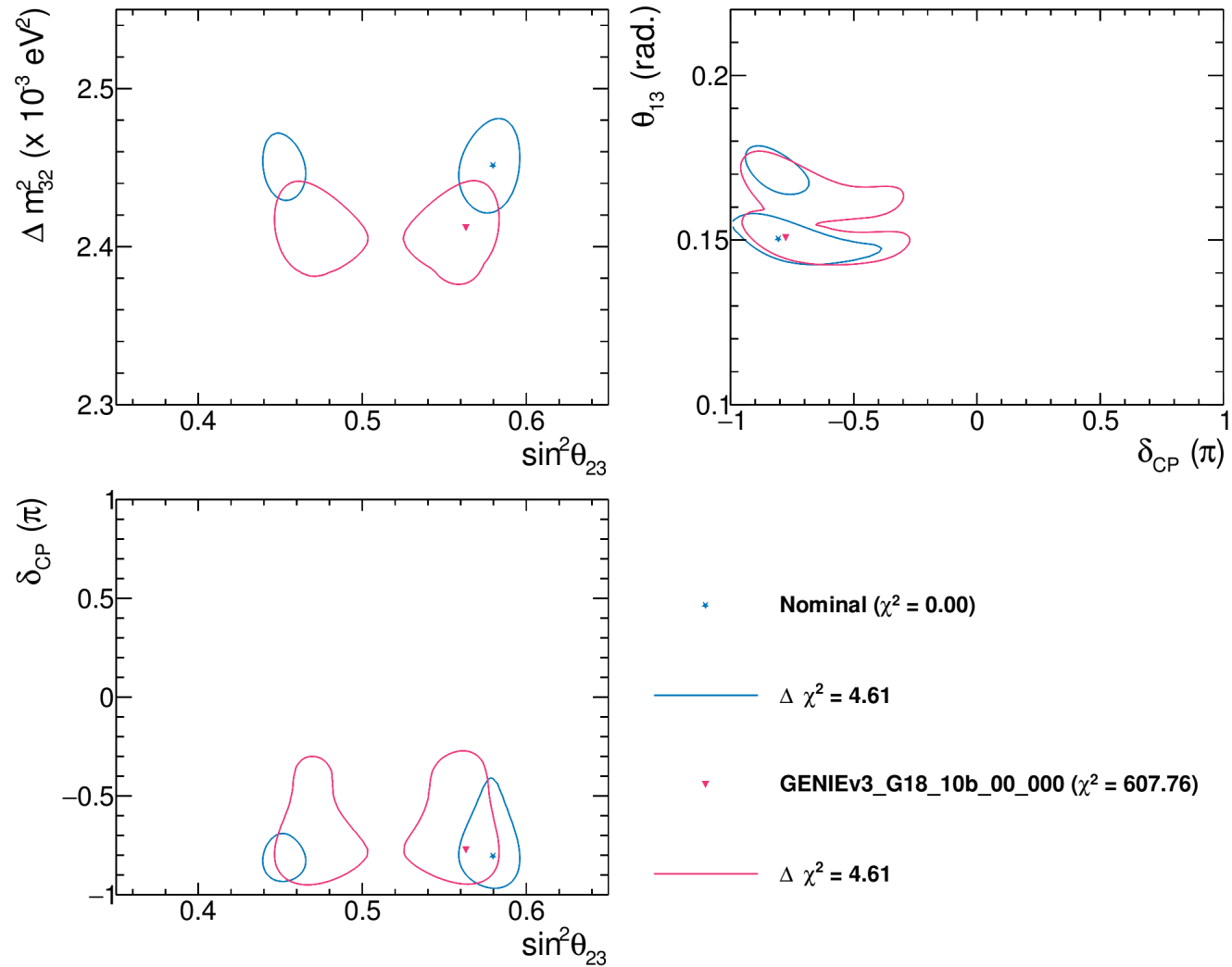
## What about fake data studies?

- ▶ Extreme variations outside the model used to produce ridiculous  $\chi^2$  values, so obviously of interest to check
- ▶ For convenience, I'm just looked at the alternative generator fake data sets that Cris Vilela made, but there are other XSEC fake data dials I could look at
- ▶ All plots show 90% confidence limits for ND+FD 7 year exposures with all systematic and oscillation parameters, and with no  $\theta_{13}$  penalty applied

# GENIEv3\_G18\_10a\_02\_11aReweightFakeData, asimov0, nopn

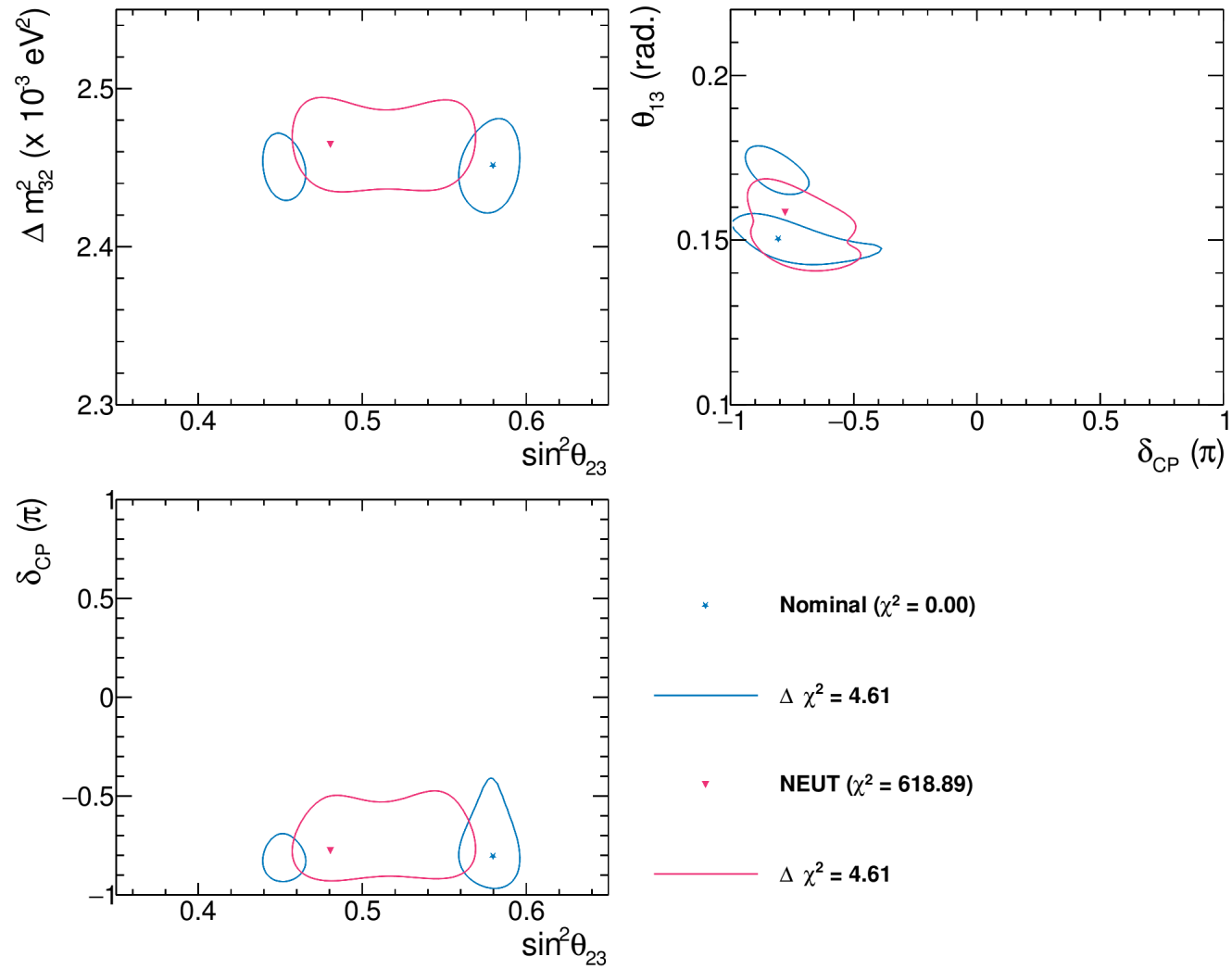


# GENIEv3\_G18\_10b\_00\_000ReweightFakeData, asimov0, nopen

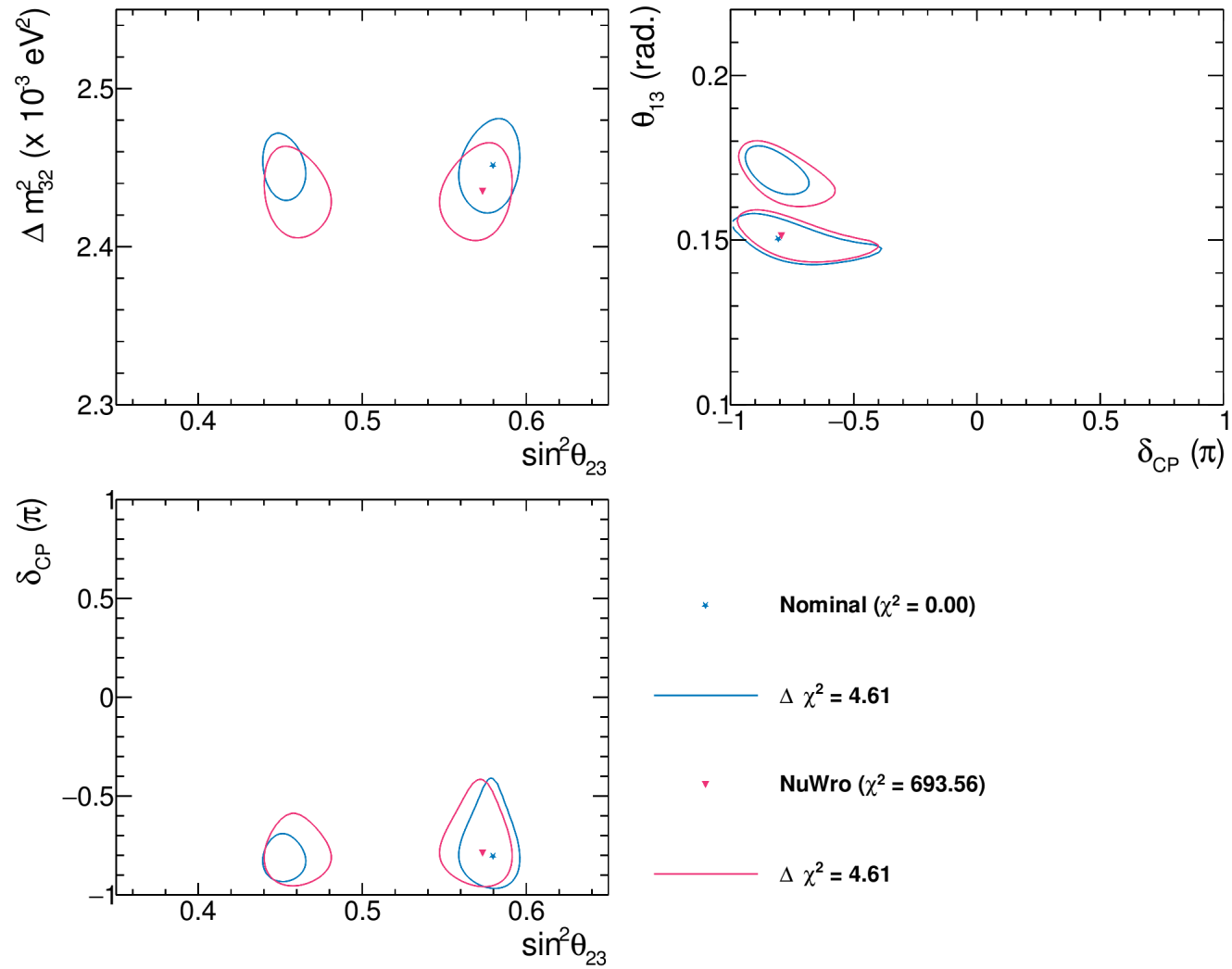




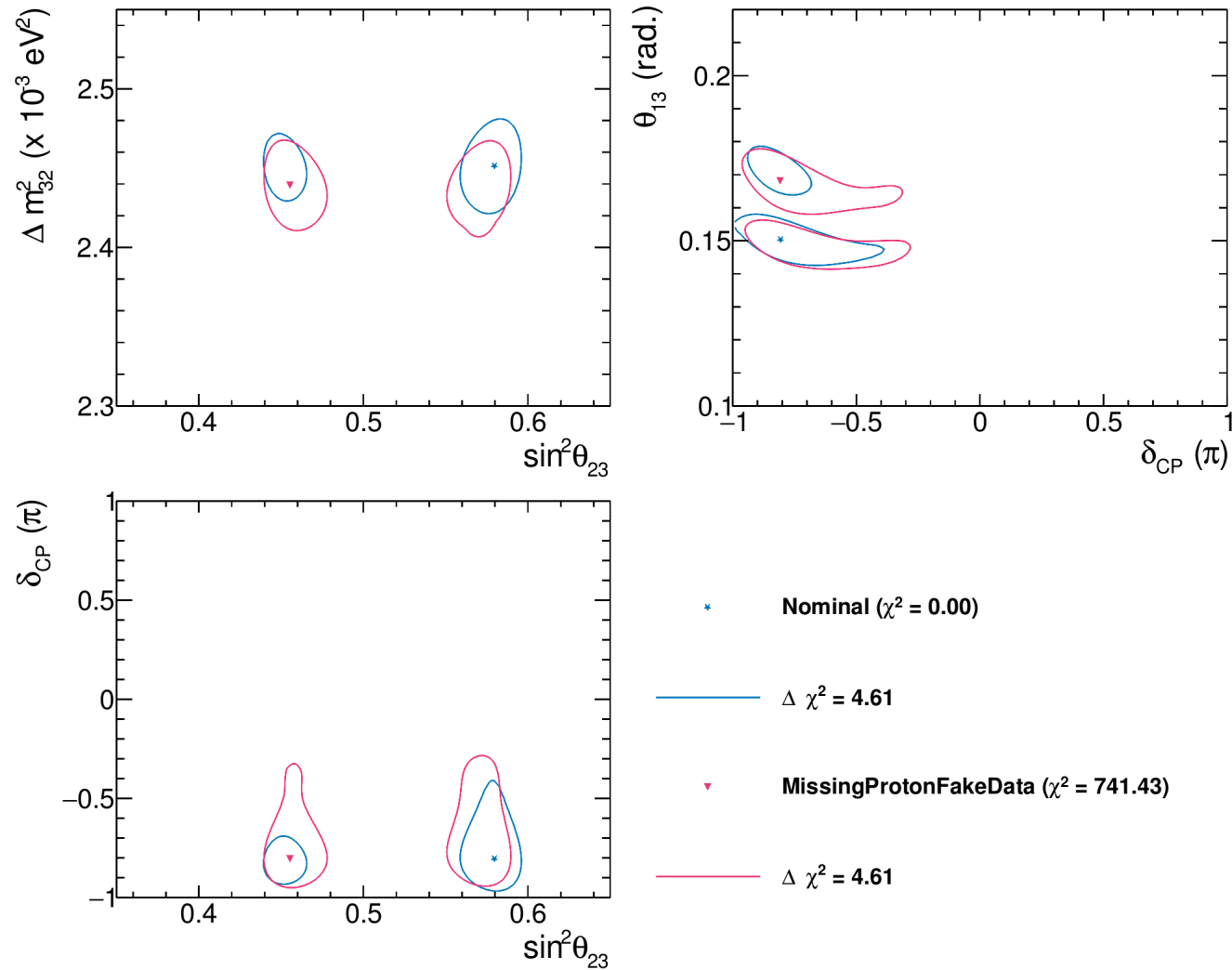
# NEUTReweightFakeData, asimov0, nopen



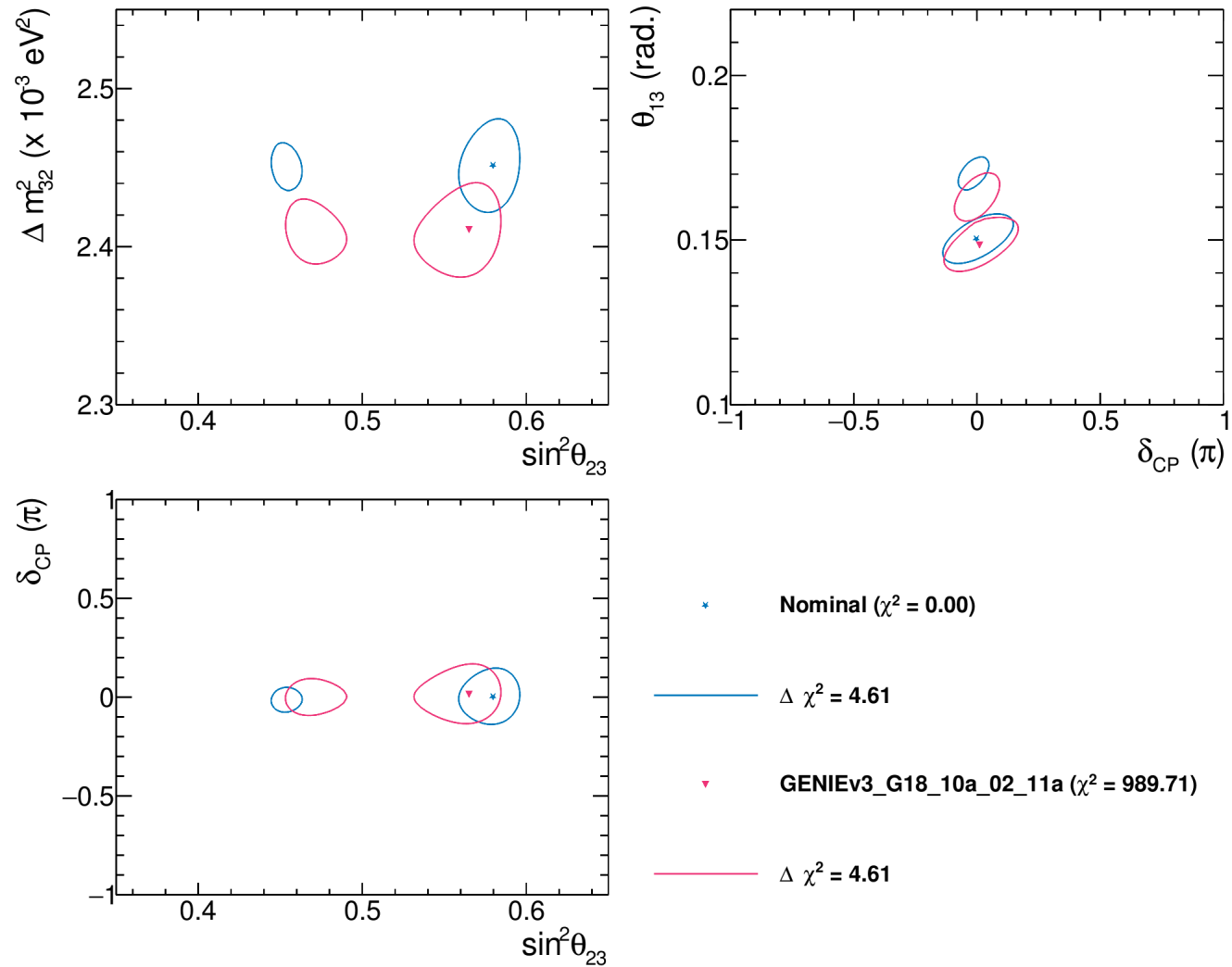
# NuWroReweightFakeData, asimov0, nopen



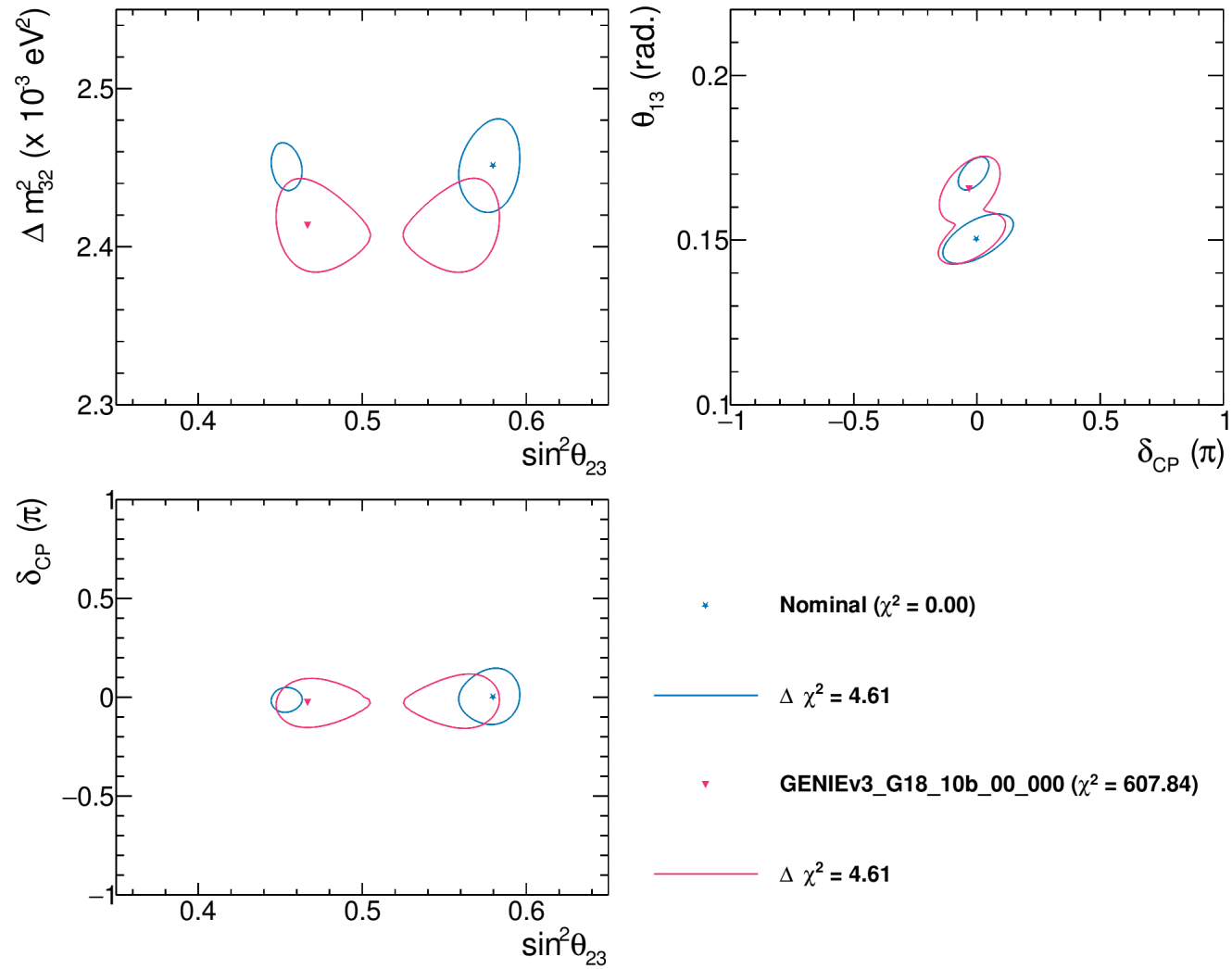
# MissingProtonFakeData, asimov0, nopen



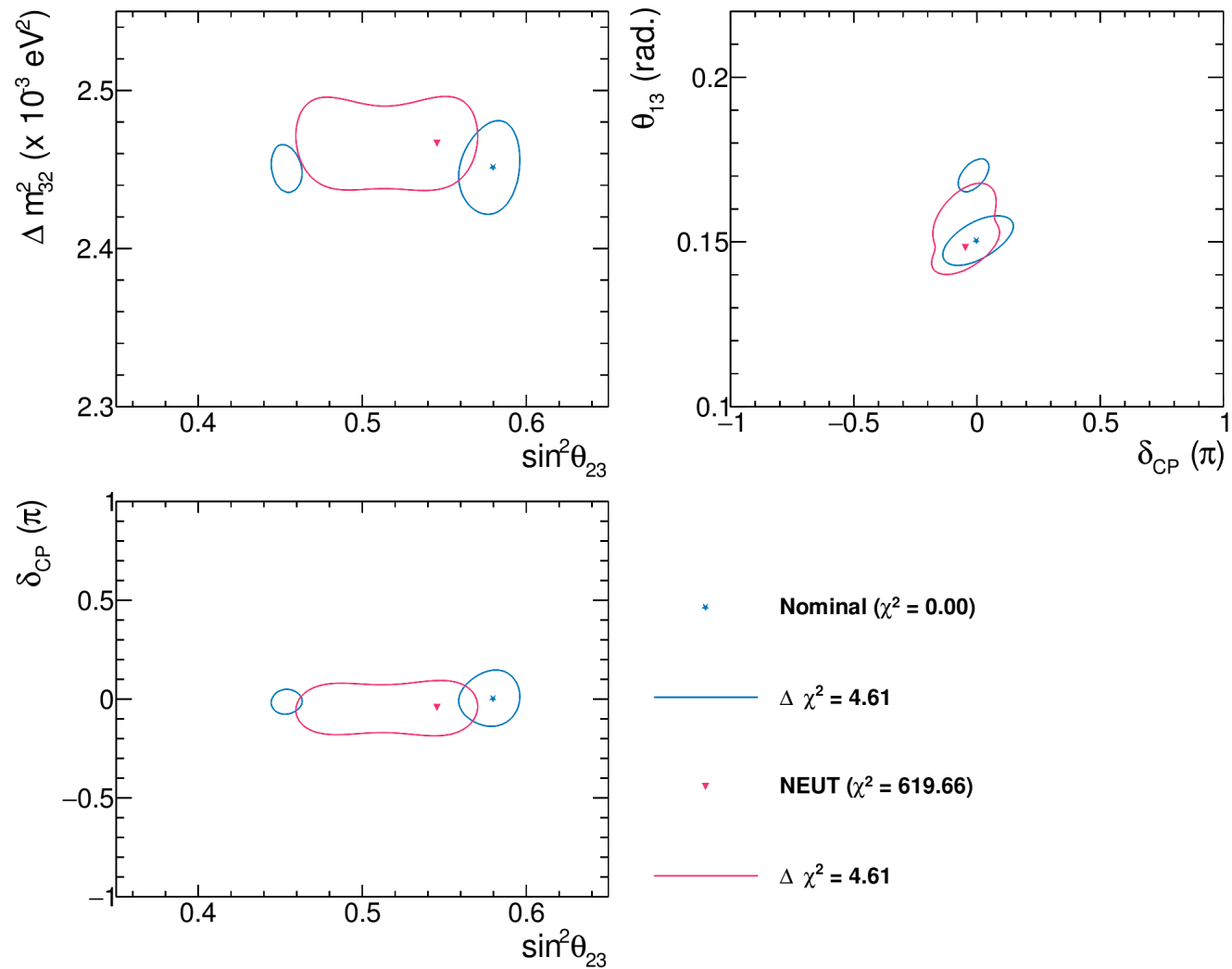
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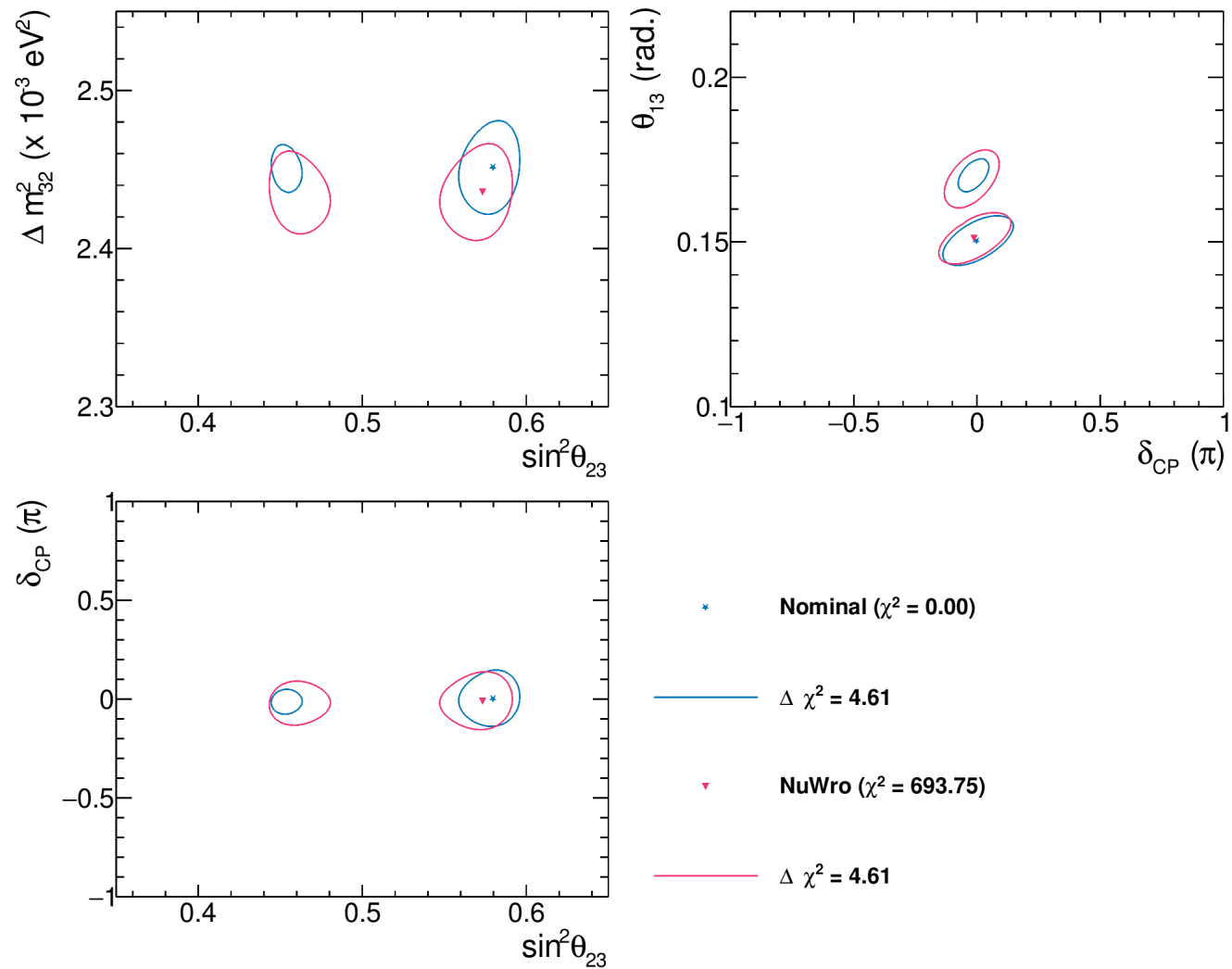
# GENIEv3\_G18\_10b\_00\_000ReweightFakeData, deltapi:0, nopen



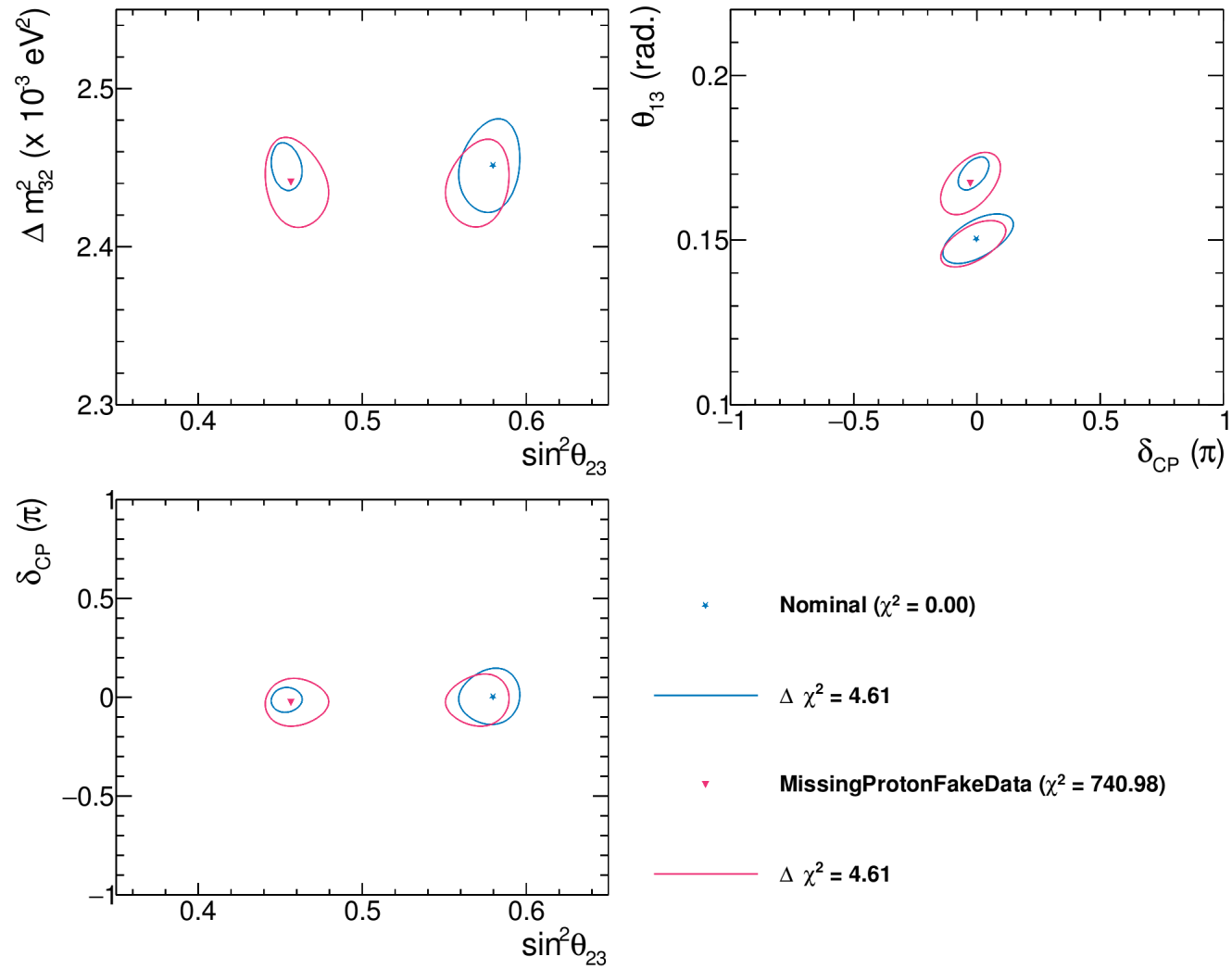
# NEUTRweightFakeData, deltapi:0, nopn



# NuWroReweightFakeData, deltapi:0, nopen

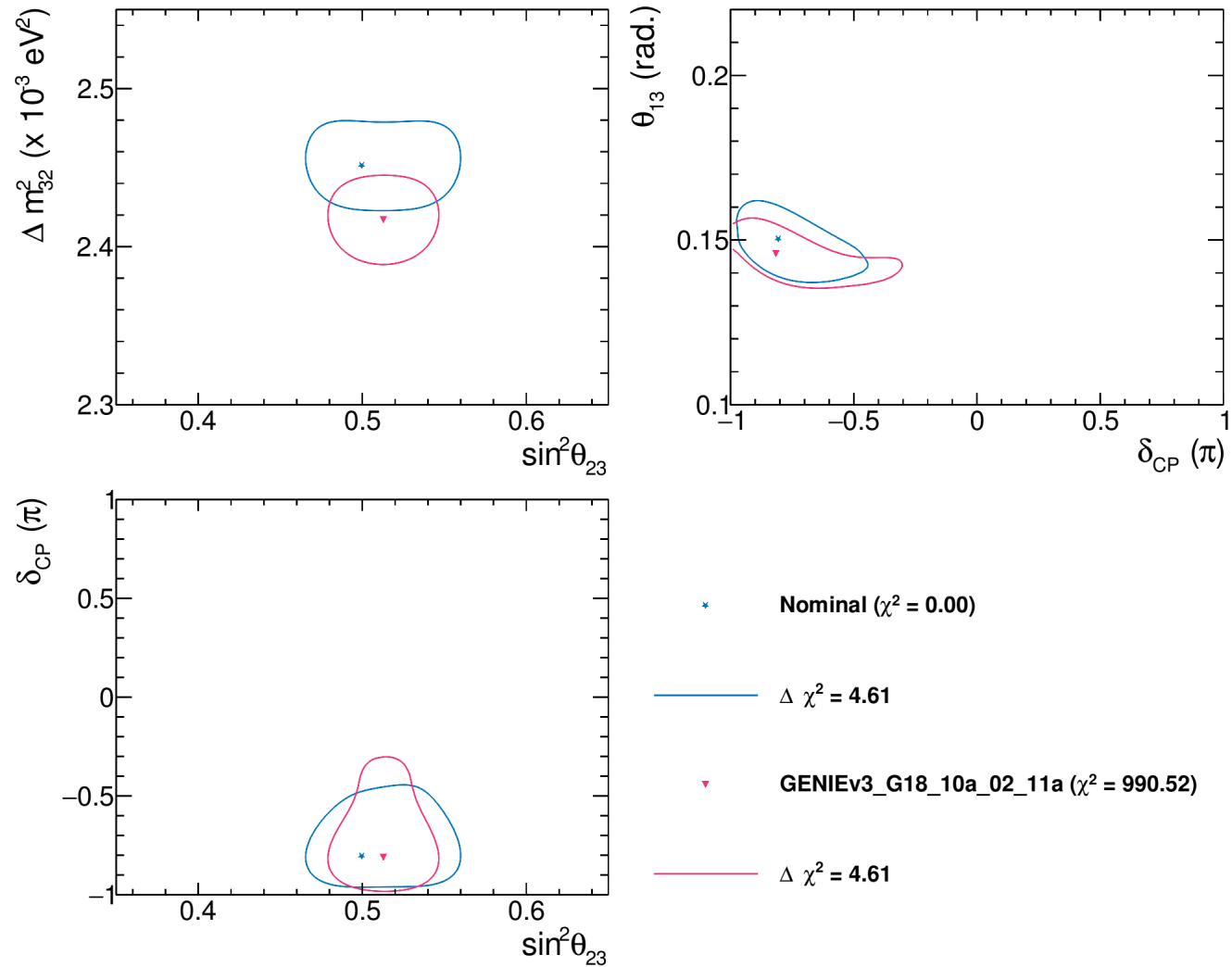


# MissingProtonFakeData, deltapi:0, nopem

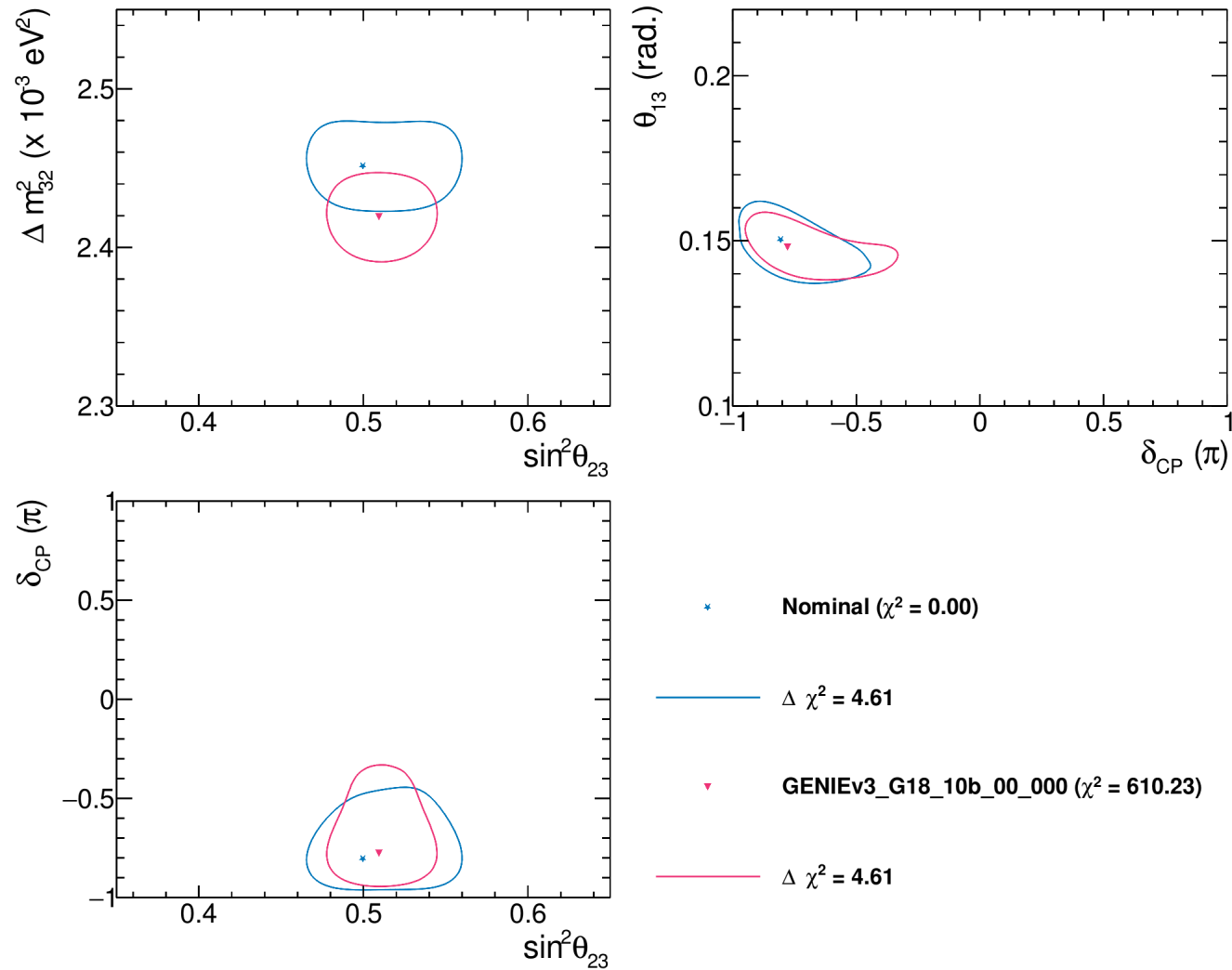




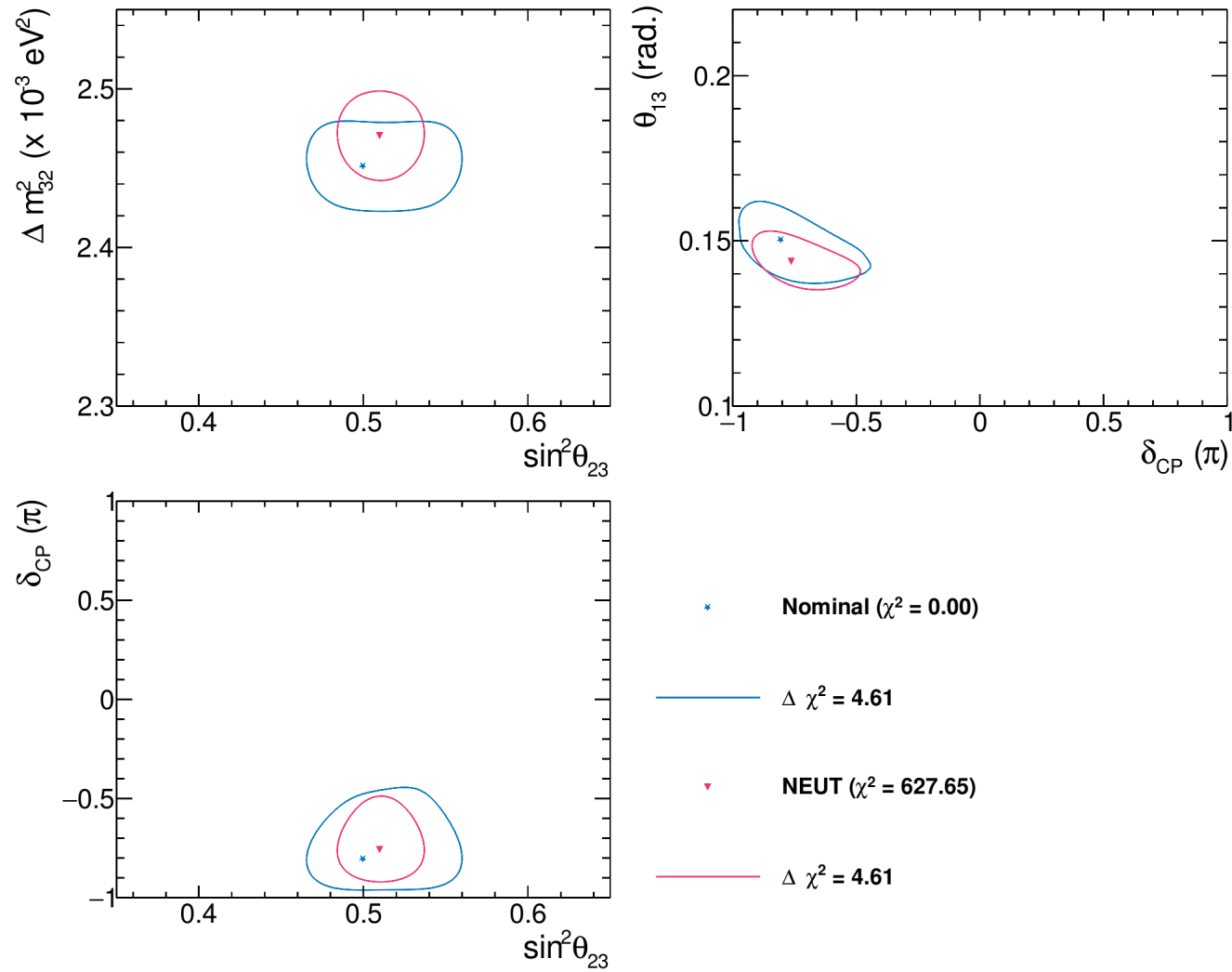
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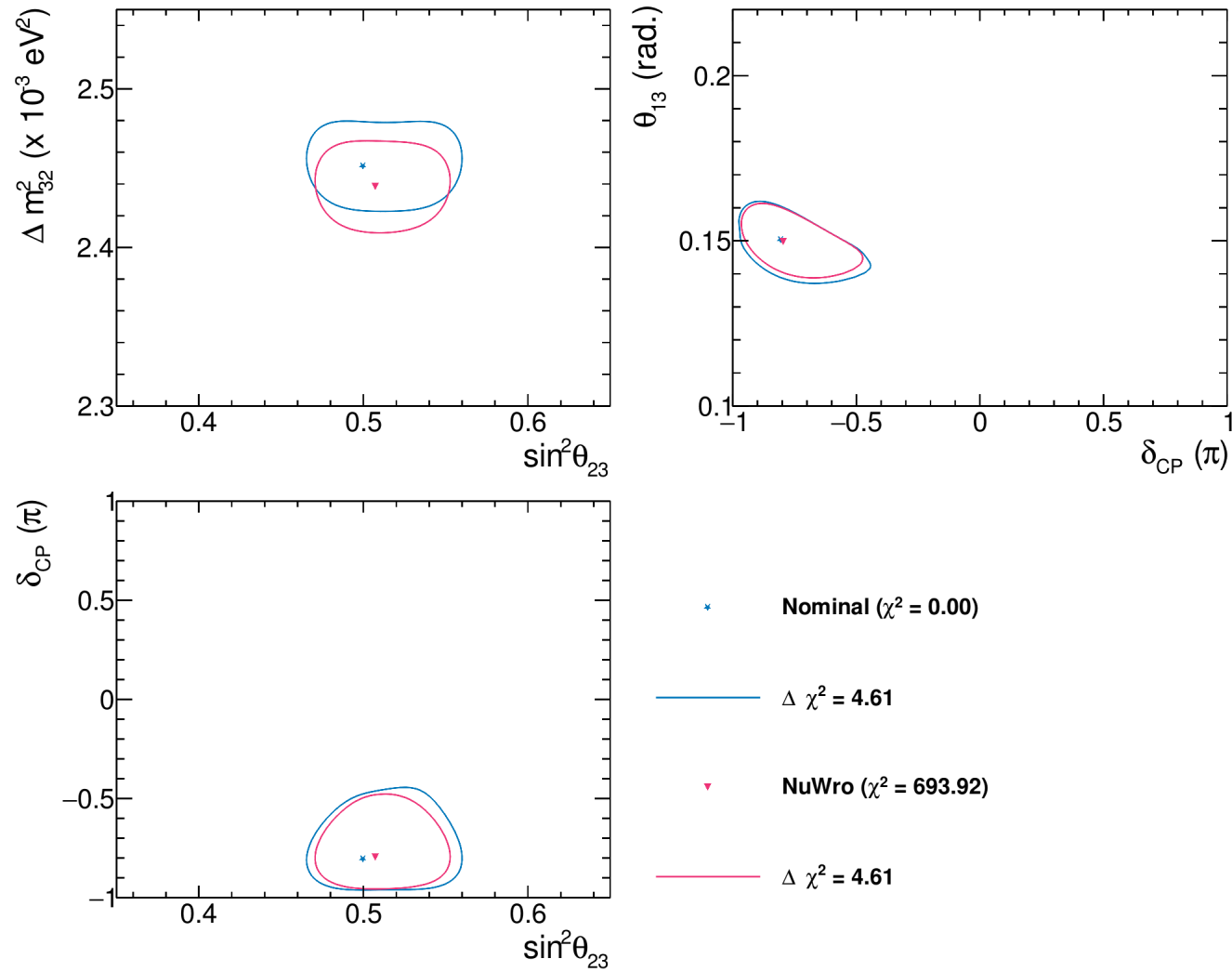
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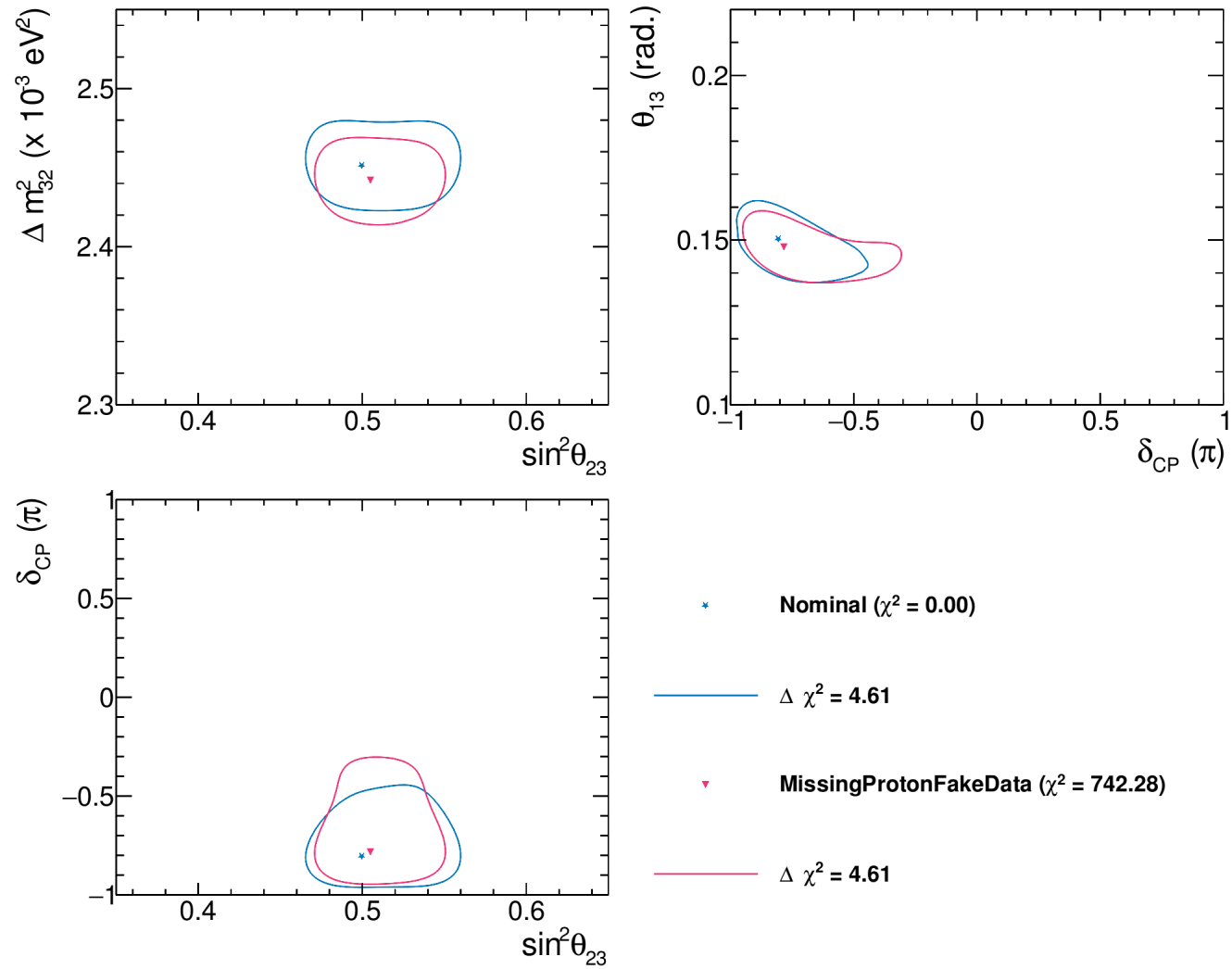
# NEUTReweightFakeData, ssth23:0.5, nopem



# NuWroReweightFakeData, ssth23:0.5, nopn



# MissingProtonFakeData, ssth23:0.5, nopcn



# Summary

- ▶ Found an issue with the ND covariance matrix
- ▶ *Luckily*, this doesn't affect the headline analysis results or low exposure paper
- ▶ Does partially mitigate the huge  $\chi^2$  values previously observed for fake data studies, which may make those an interesting area to re-explore
- ▶ But no new huge biases to show off yet...