

# NUCLEON CHARGES ON 2+1 FLAVOR NME CLOVER ENSEMBLES

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# Rich Physics

## Precision tests of the Standard Model

- $V_{ud}$  from  $\beta$  decay to test CKM unitarity, spin of the nucleon
- Searches for new scalar and tensor interactions
- Dark matter and EDM phenomenology

## Nucleon isovector charges probed in neutron $\beta$ decay experiments

- $g_A$ : neutron  $\beta$  decay
- $g_S$ : scalar BSM interactions
- $g_T$ : tensor BSM interactions and EDMs

# Status

Lattice calculation of nucleon matrix elements

- Eleven 2+1-flavor NME Clover Ensembles

- Spectrum and scale setting:

[arXiv:2601.10857](https://arxiv.org/abs/2601.10857)

- Isovector Nucleon Charges  $g_A, g_S, g_T$

(under analysis)

- Axial Form factors

(under analysis)

- Electric and Magnetic form factors

(under analysis)

- Second Mellin moments:  $\langle x \rangle_q, \langle x \rangle_{\Delta q}, \langle x \rangle_{\delta q}$

(To appear on arXiv next week)

Controlling systematics:

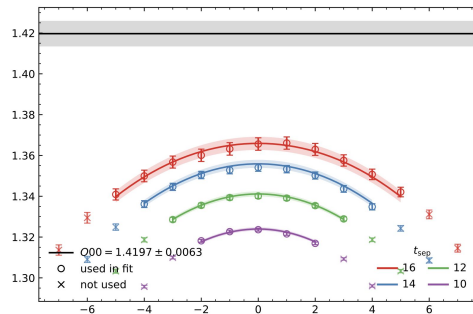
- Removing contributions of excited states
- Chiral – continuum - finite volume extrapolation
- Renormalization

[arXiv:2601.10857](https://arxiv.org/abs/2601.10857)

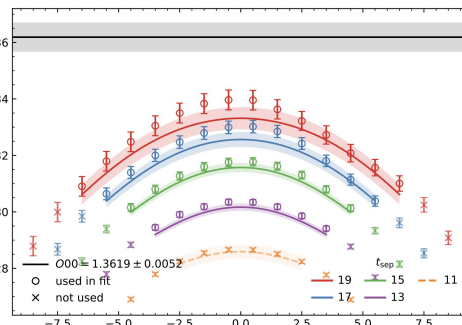
# Lattice Details

| Ens. ID          | Grid Size         | $\beta$ | c <sub>sw</sub> | a (fm) | Mpi |      | L (fm) | Total Lattices |
|------------------|-------------------|---------|-----------------|--------|-----|------|--------|----------------|
| <b>a117m310</b>  | $32^3 \times 96$  | 6.1     | 1.249310        | 0.117  | 310 | 5.85 | 3.7    | 4865           |
| <b>a087m290L</b> | $48^3 \times 128$ | 6.3     | 1.205366        | 0.087  | 289 | 6.16 | 4.2    | 6223           |
| <b>a087m230</b>  | $48^3 \times 128$ | 6.3     | 1.205366        | 0.087  | 233 | 5.0  | 4.2    | 5200           |
| <b>a087m230X</b> | $48^3 \times 128$ | 6.3     | 1.205366        | 0.087  | 228 | 5.0  | 4.2    | 3167           |
| <b>a086m180L</b> | $64^3 \times 128$ | 6.3     | 1.205366        | 0.086  | 179 | 5.1  | 5.5    | 6622           |
| <b>a068m290</b>  | $48^3 \times 128$ | 6.5     | 1.170082        | 0.068  | 290 | 4.18 | 3.3    | 7620           |
| <b>a067m230</b>  | $64^3 \times 192$ | 6.5     | 1.170082        | 0.068  | 234 | 5.2  | 4.4    | 3604           |
| <b>a067m175</b>  | $72^3 \times 192$ | 6.5     | 1.170082        | 0.068  | 175 | 4.4  | 4.9    | 5556           |
| <b>a067m135</b>  | $96^3 \times 192$ | 6.5     | 1.170082        | 0.067  | 135 | 4.4  | 6.4    | 2904           |
| <b>a053m295</b>  | $64^3 \times 192$ | 6.7     | 1.142727        | 0.053  | 295 | 4.8  | 3.4    | 5301           |
| <b>a053m230</b>  | $72^3 \times 192$ | 6.7     | 1.142727        | 0.053  | 226 | 4.5  | 3.8    | 3331           |

# Isovector Axial Charge

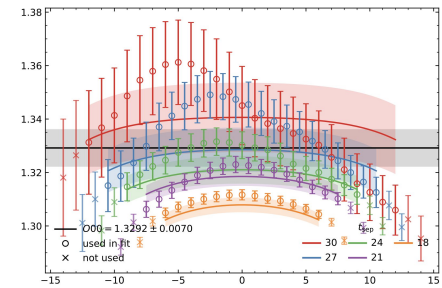


a12m310

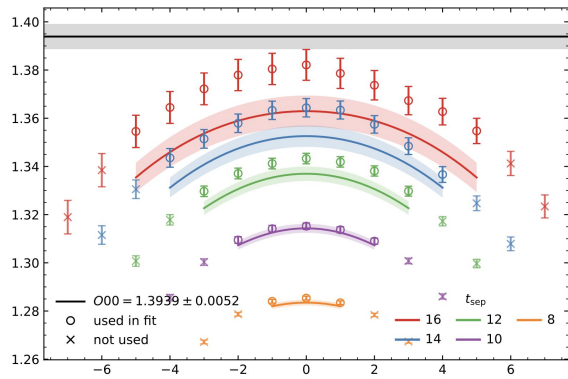


a087m290L

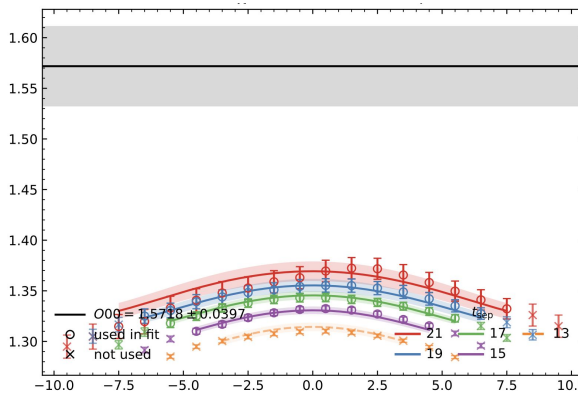
a068m290



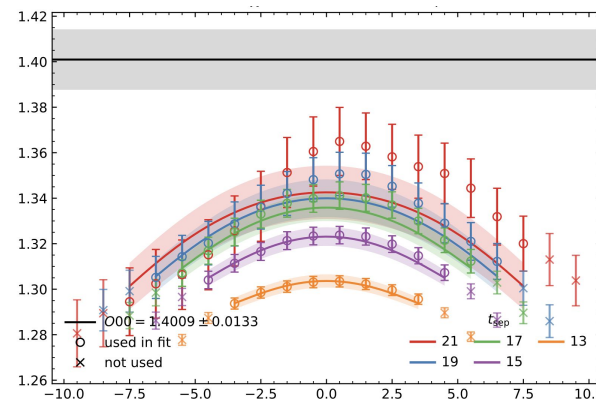
a053m295



a086m180L

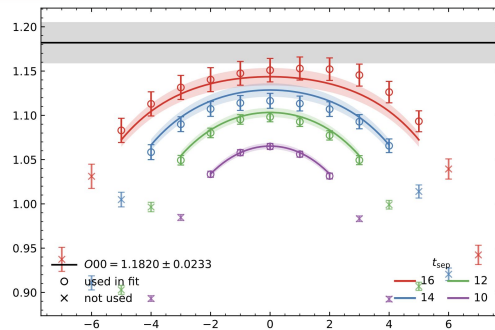


a067m175



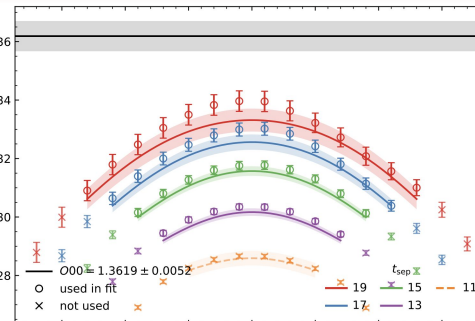
a067m135

# Isovector Scalar Charge

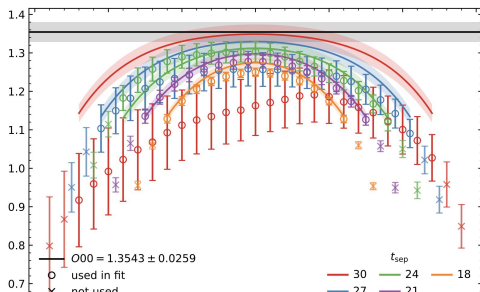


$a_{12}m_{310}$

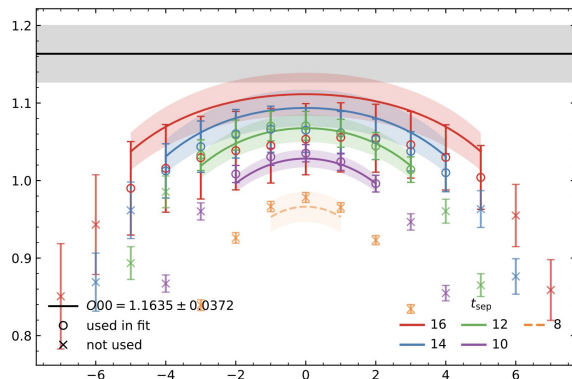
$a_{087}m_{290L}$



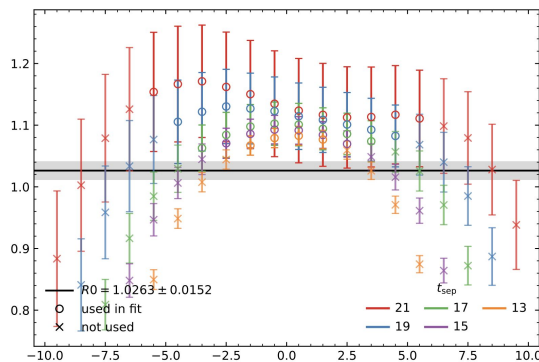
$a_{068}m_{290}$



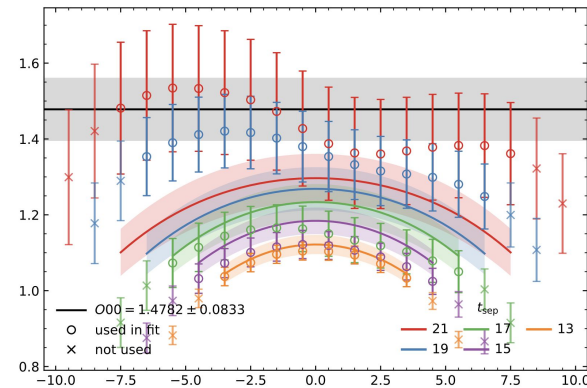
$a_{053}m_{295}$



$a_{086}m_{180L}$



$a_{067}m_{175}$

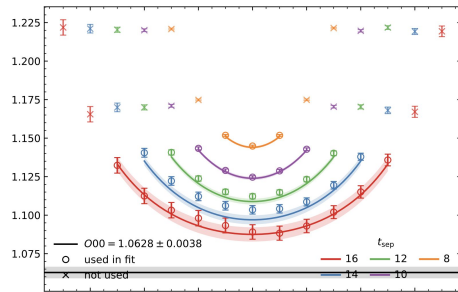


$a_{067}m_{135}$

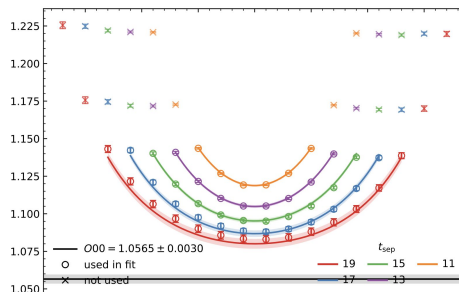
# Isovector Tensor Charge



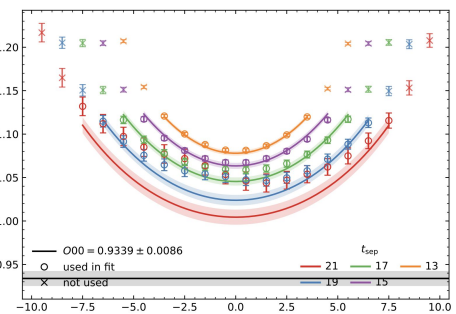
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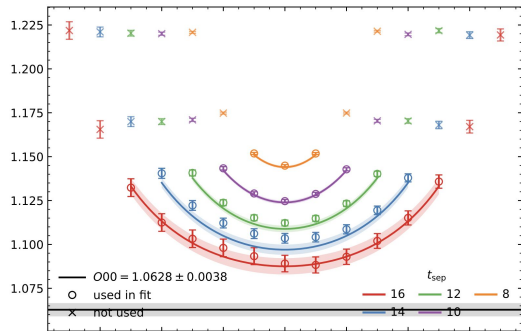
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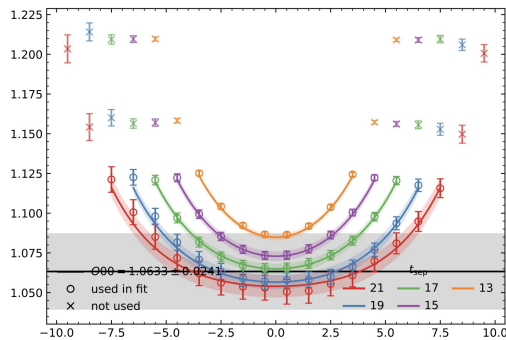
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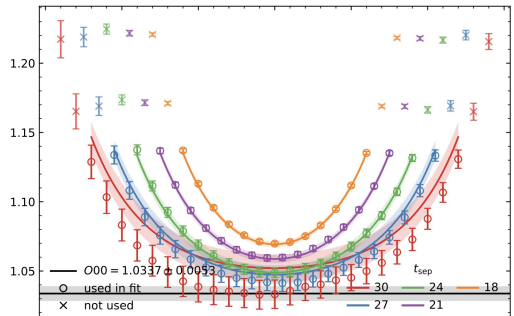
a053m295



a086m180L



a067m175



a067m135

# Moments of distributions

JHEP 21, 004 (2020)

arXiv:



$$\langle x \rangle_q = \int_0^1 x [q(x) + \bar{q}(x)] dx$$

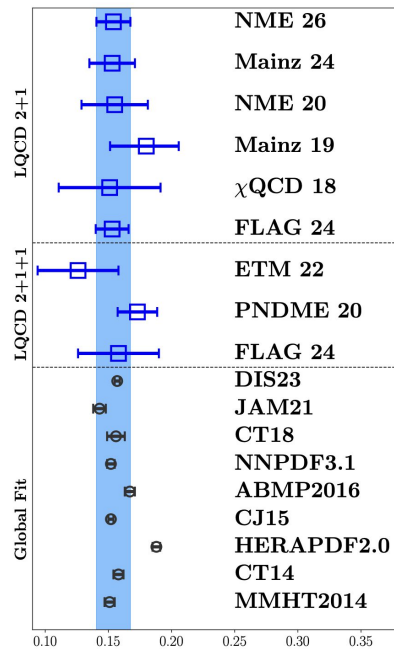
$$\langle x \rangle_{\Delta q} = \int_0^1 x [\Delta q(x) + \Delta \bar{q}(x)] dx$$

$$\langle x \rangle_{\delta q} = \int_0^1 x [\delta q(x) + \delta \bar{q}(x)] dx$$

# Status of results:

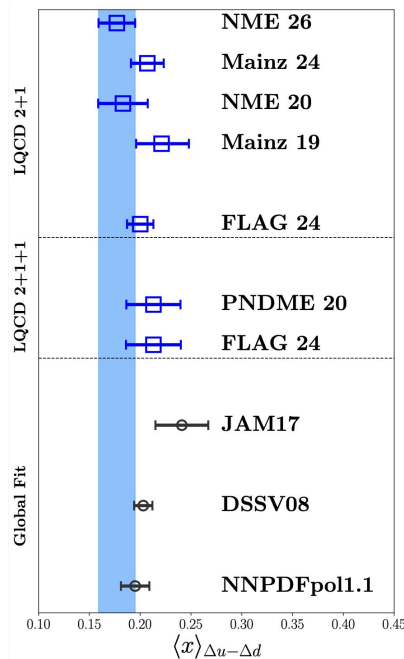


$$\langle x \rangle_q = 0.154(10)(9)$$



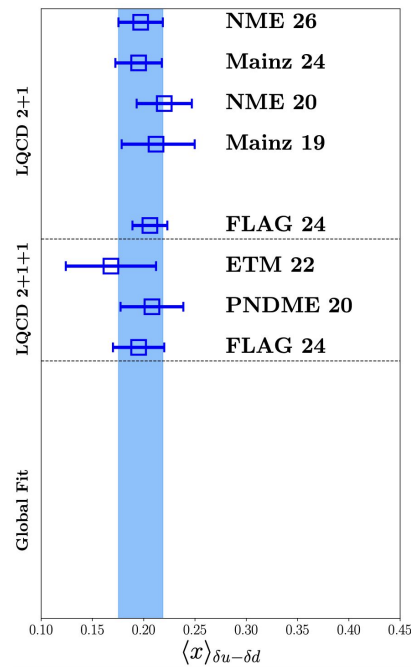
Momentum Fraction

$$\langle x \rangle_{\Delta q} = 0.177(10)(15)$$



Helicity Moment

$$\langle x \rangle_{\delta q} = 0.197(12)(18)$$



Transversity Moment



# Conclusions

- Need higher statistics
- Need more ensembles

All these results to be published  
by the end of this year

# CKM Unitarity

$$V_{\text{CKM}} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

First Row Unitarity measure  $\Delta_{\text{CKM}} = |V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2 - 1$

$|V_{ub}| \sim 10^{-3}$ , negligible

Current  $\Delta_{\text{CKM}}$ :

- 2.8 $\sigma$  deviation when using (K $\ell$ 3 , K $\mu$ 2 / $\pi\mu$ 2)
- 3.0 $\sigma$  deviation when using (K $\ell$ 3 ,  $\beta$ -decay)
- 1.7 $\sigma$  deviation when using (K $\mu$ 2 / $\pi\mu$ 2 ,  $\beta$ -decay)