Preliminary Analysis for the unpolarized nucleon PDF on the ensemble "cl21_48_96_b6p3_m0p2416_m0p2050" (a.k.a. "a091m170")

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Calculation details, statistics

- $L/a = 48, T/a = 96, a \simeq 0.091$ fm
- $m_\pi \simeq 166$ MeV, $m_N \simeq 932$ MeV

- Three streams of configurations:
    1. "main" stream, 127 configurations
    2. "stream-1000", 76 configurations
    3. "stream-1200", 84 configurations

Total of 287 configurations

- 4 values of $t_0/a = 0, 24, 48, 72$
- Momenta $\mathrm{abs}(P_z) = 0, 1, 2$. Displacements $\mathrm{abs}(z_3) = 0 \dots 8$

$\Rightarrow 4592$ statistics

- 5 values of $t_{\mathrm{sep}}/a = 4, 6, 8, 10, 12$
- Genprops produced on CPU and GPU partitions of Jean Zay (Christos)
- Two- and three-point functions produced on Frontera (Colin)
- This analysis is with the **"incorrect"** eigenvectors

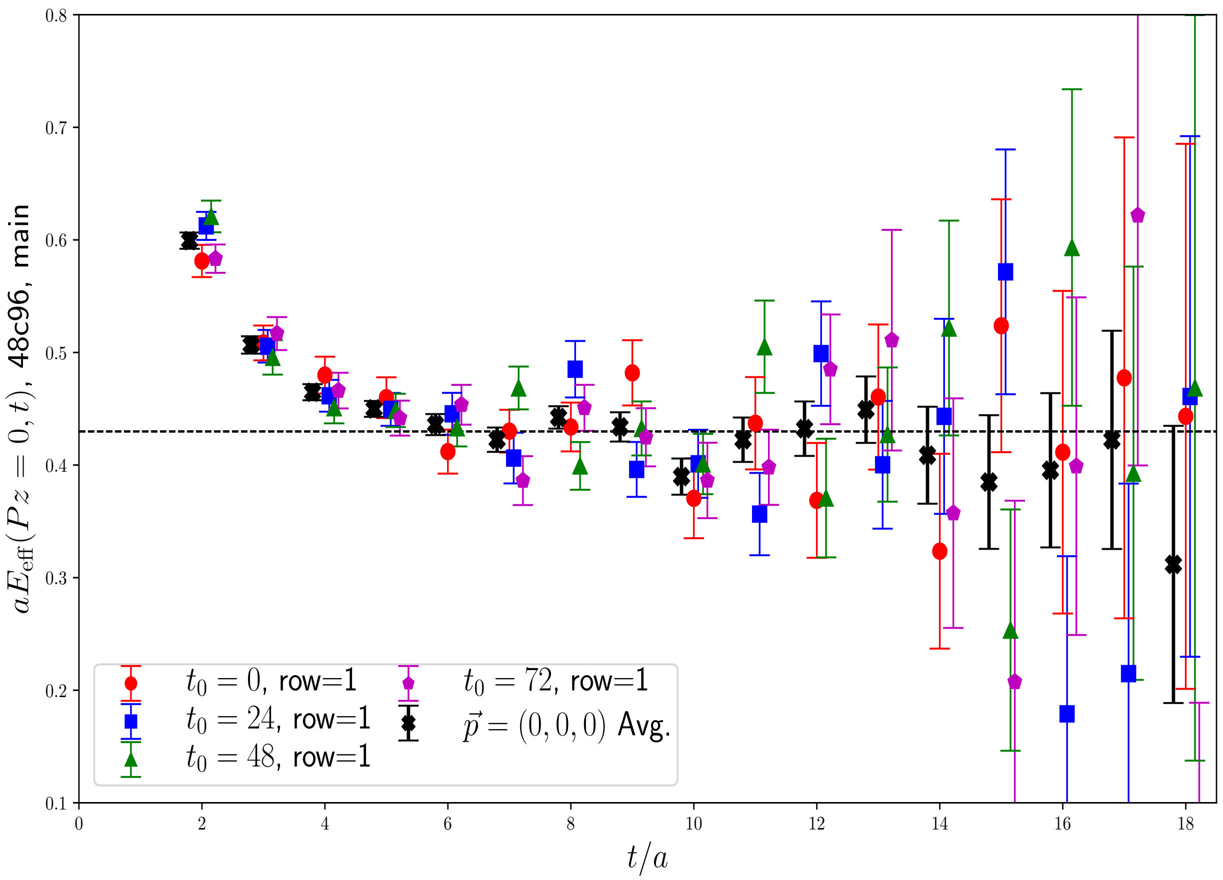
Averaging the two-point function

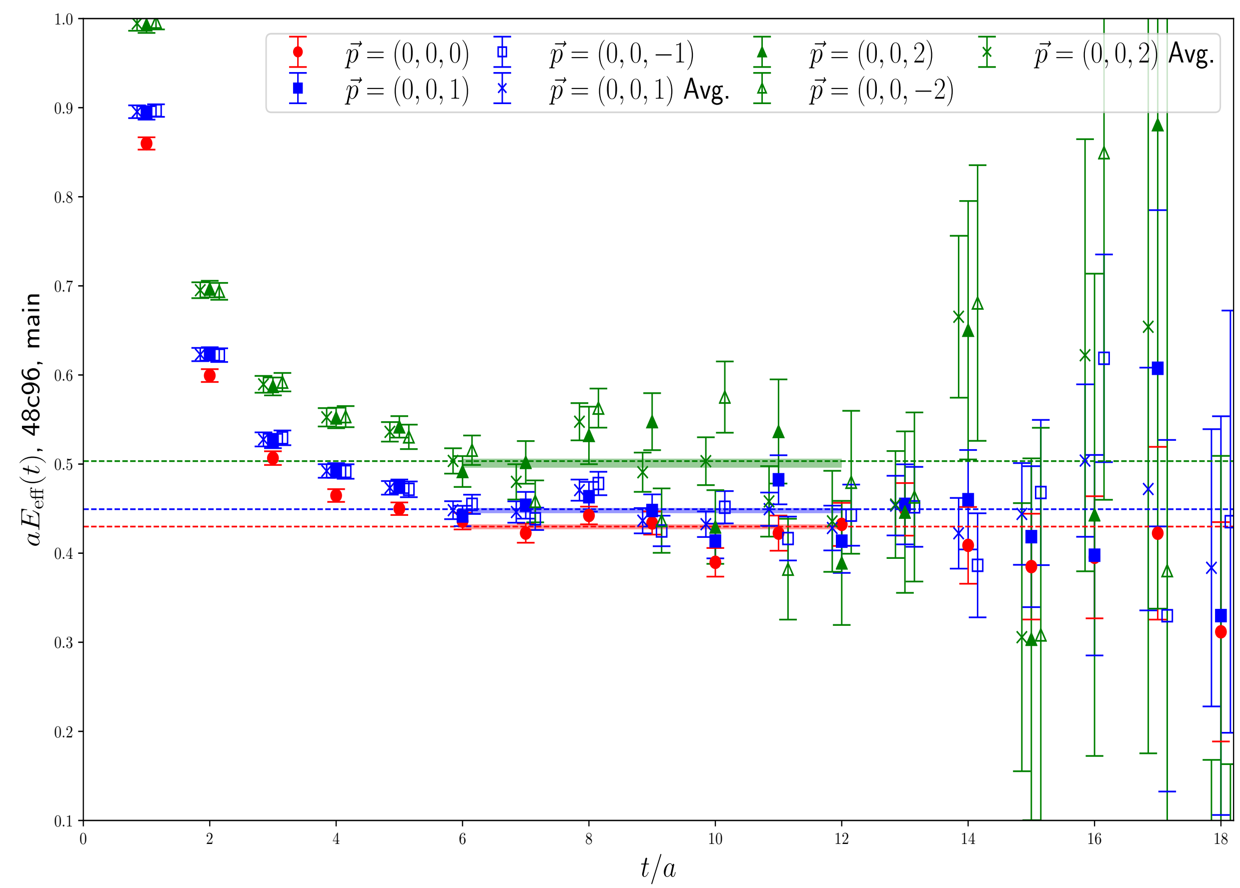
Two-point correlator: $C_{2,\text{raw}} = f(t_0; P_z, t_s)$.

<u>Step 1:</u> Average over t_0

<u>Step 2:</u> Average over positive/negative momenta P_z

Effective energy: $$aE_{\text{eff}}(P_z, t_s) = \log\left(\frac{C_2(P_z, t_s)}{C_2(P_z, t_s + 1)}\right)$$





Averaging the three-point function

Three-point correlator: $C_{3,\text{raw}} = f(t_0; P_z, z_3\ ;\ t_s, t_{\text{ins}})$. Consider only $\Gamma = \gamma_t$ for now

<u>Step 1</u>: Average over t_0

<u>Step 2</u>: Average over positive/negative (P_z, z_3) combinations. There are 4 cases:

- $P_z = 0, z_3 = 0$: There is only one combination in this case.
- $P_z = 0, z_3 \neq 0$:
  - Real part: $\text{Re}\left[C_3(0, z_3)\right] = \frac{1}{2}\left[C_3(0, +z_3) + C_3(0, -z_3)\right]$
  - Imag. Part: $\text{Im}\left[C_3(0, z_3)\right] = \frac{1}{2}\left[C_3(0, +z_3) - C_3(0, -z_3)\right]$
- $P_z \neq 0, z_3 = 0$:
  - Real part: $\text{Re}\left[C_3(P_z, 0)\right] = \frac{1}{2}\left[C_3(+P_z, 0) + C_3(-P_z, 0)\right]$
  - Imag. Part: $\text{Im}\left[C_3(P_z, 0)\right] = \frac{1}{2}\left[C_3(+P_z, 0) - C_3(-P_z, 0)\right]$
- $P_z \neq 0, z_3 \neq 0$:

P_z	z_3	ν	Re	Im
+	+	+	+	+
-	-	+	+	+
+	-	-	+	-
-	+	-	+	-

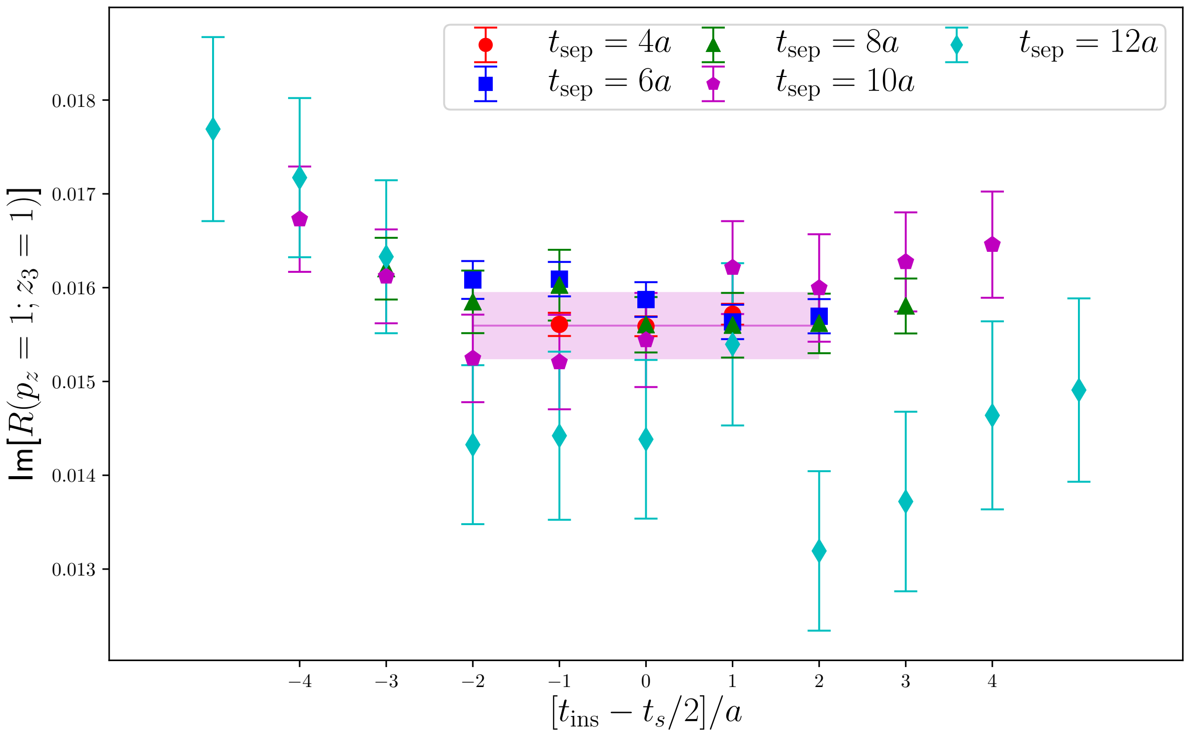
  - Real part: $\text{Re}\left[C_3(P_z, z_3)\right] = \frac{1}{4}\left[C_3(+P_z, +z_3) + C_3(+P_z, -z_3) + C_3(-P_z, +z_3) + C_3(-P_z, -z_3)\right]$
  - Imag. Part: $\text{Im}\left[C_3(P_z, z_3)\right] = \frac{1}{4}\left[C_3(+P_z, +z_3) - C_3(+P_z, -z_3) - C_3(-P_z, +z_3) + C_3(-P_z, -z_3)\right]$

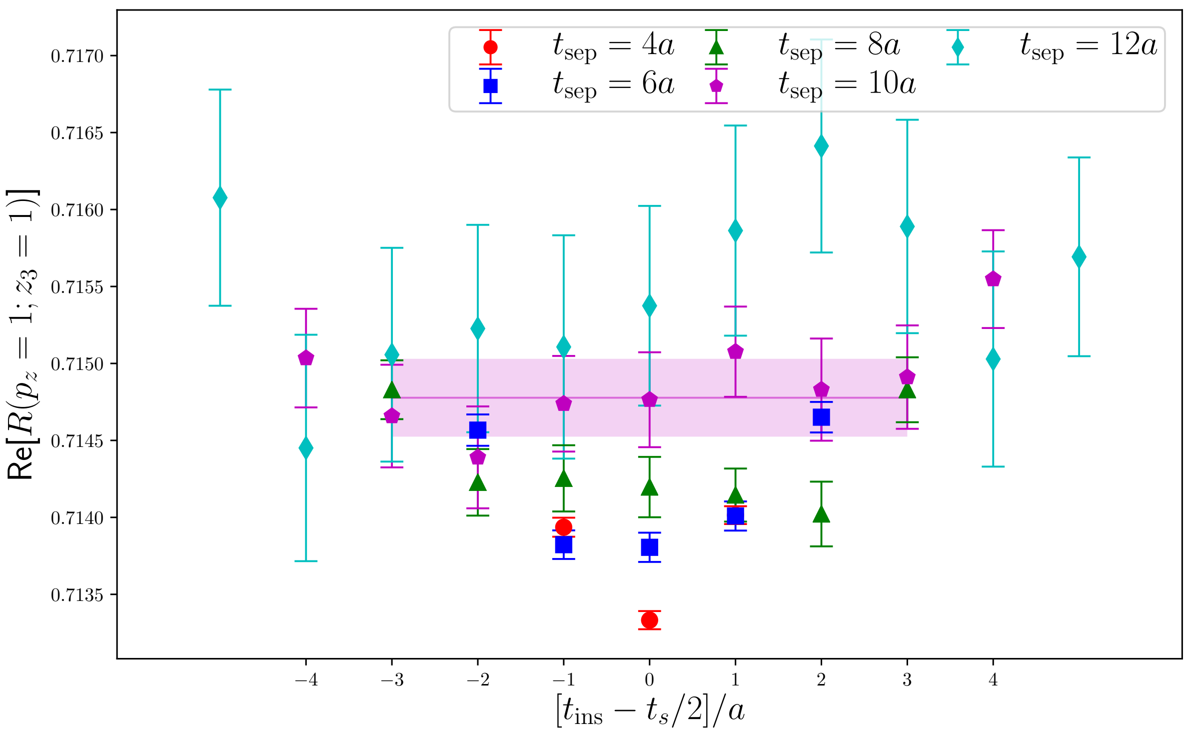
Ratio of three- and two-point functions

Matrix element extraction / ground state dominance

Ratio of 3pt/2pt functions: $R(P_z, z_3; t_s, t_{\text{ins}}) = \dfrac{C_3(P_z, z_3; t_s, t_{\text{ins}})}{C_2(P_z, t_s)}$

- Method 1: Constant fits to plateau region of the ratio
  - for each t_s, perform constant fits on the ratio on multiple ranges beginning on the whole range of t_{ins}, excluding the source and sink
  - each fit range is decreased by 1 point on each of the source and sink sides, until 3 points are considered
  - the "best" fit range for each t_s is the longest one for which $\chi^2 < 0.9$
  - ($t_s = 4a$ consists only of three points, just select middle point in this case)





Ratio of three- and two-point functions

Matrix element extraction / ground state dominance

Ratio of 3pt/2pt functions: $R(P_z, z_3; t_s, t_{\text{ins}}) = \dfrac{C_3(P_z, z_3; t_s, t_{\text{ins}})}{C_2(P_z, t_s)}$

- <u>Method 2:</u> Summation method

$$R_{\text{sum}}(P_z, z_3; t_s) = \sum_{t_{\text{ins}}=1}^{t_s-1} R(P_z, z_3; t_s, t_{\text{ins}})$$

$$R_{\text{r-sum}}(P_z, z_3; t_s^i) = \frac{R_{\text{sum}}(P_z, z_3; t_s^{i+1}) - R_{\text{sum}}(P_z, z_3; t_s^i)}{t_s^{i+1} - t_s^i} = M + Ae^{-\Delta E t_s}$$

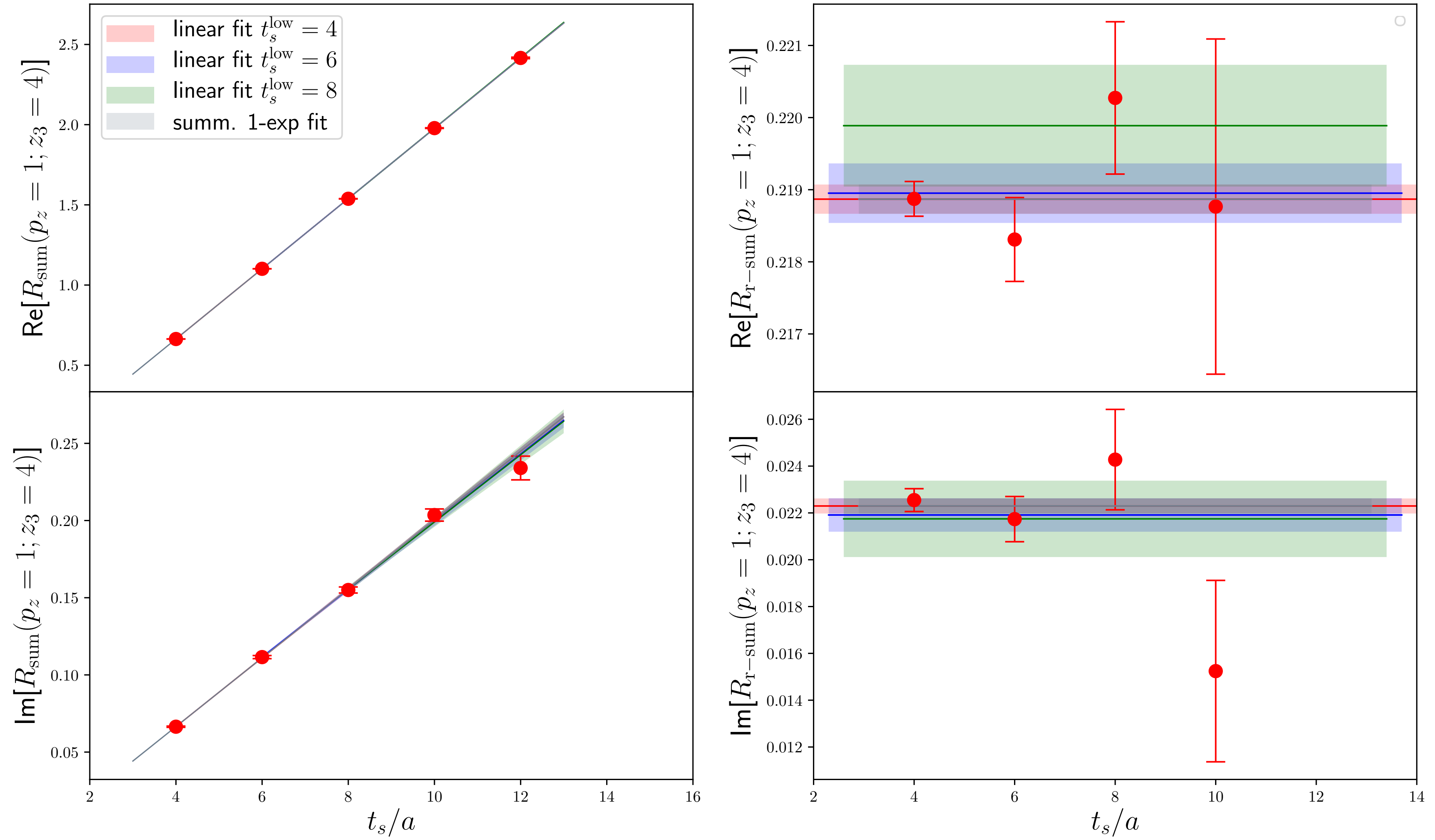
- linear fits of the form

  $R_{\text{sum}}(t_s) = C_1 + M\, t_s$

  - three choices of t_s^{low} (where the linear fit starts)

- 1-exp. fit of the form

  $R_{\text{sum}}(t_s) = C_1 + M\, t_s + C_2\, t_s\, e^{-\Delta E t_s}$



Ratio of three- and two-point functions
Matrix element extraction / ground state dominance

Ratio of 3pt/2pt functions: $R(P_z, z_3; t_s, t_{\rm ins}) = \dfrac{C_3(P_z, z_3; t_s, t_{\rm ins})}{C_2(P_z, t_s)}$

- Method 2: Summation method

$$R_{\rm sum}(P_z, z_3; t_s) = \sum_{t_{\rm ins}=1}^{t_s-1} R(P_z, z_3; t_s, t_{\rm ins}) \qquad R_{\rm r-sum}(P_z, z_3; t_s^i) = \frac{R_{\rm sum}(P_z, z_3; t_s^{i+1}) - R_{\rm sum}(P_z, z_3; t_s^i)}{t_s^{i+1} - t_s^i} = M + Ae^{-\Delta E t_s}$$

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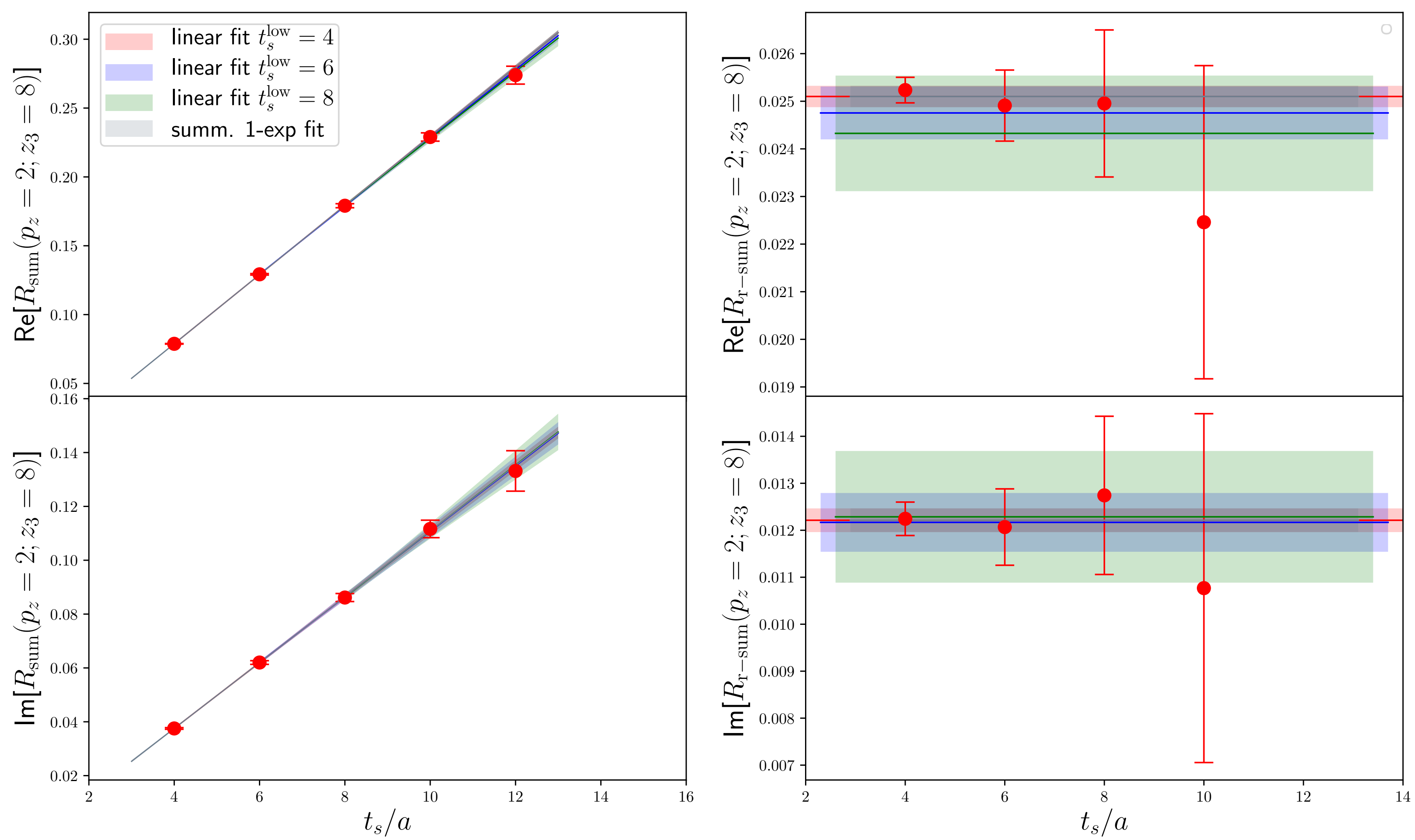
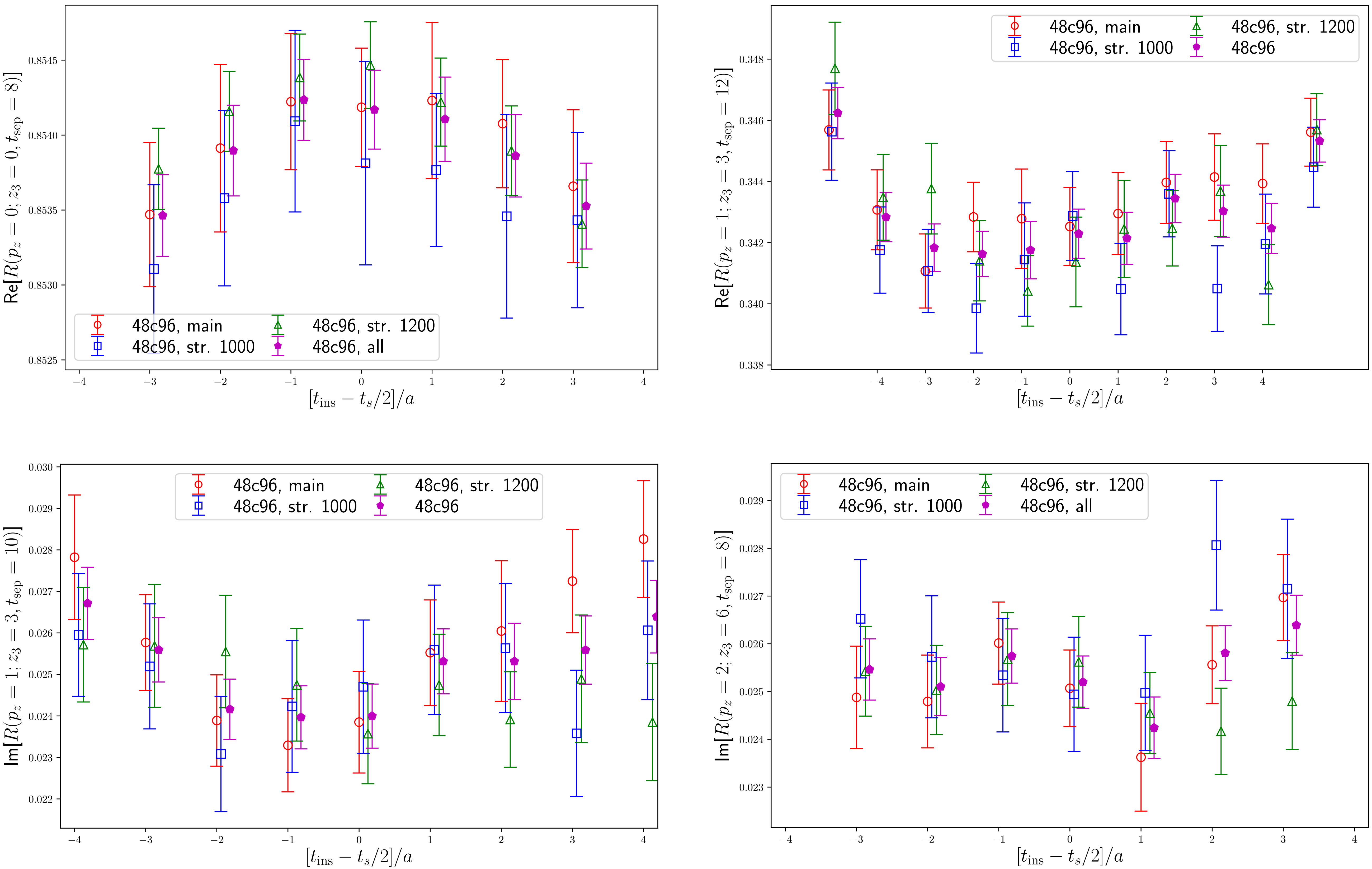
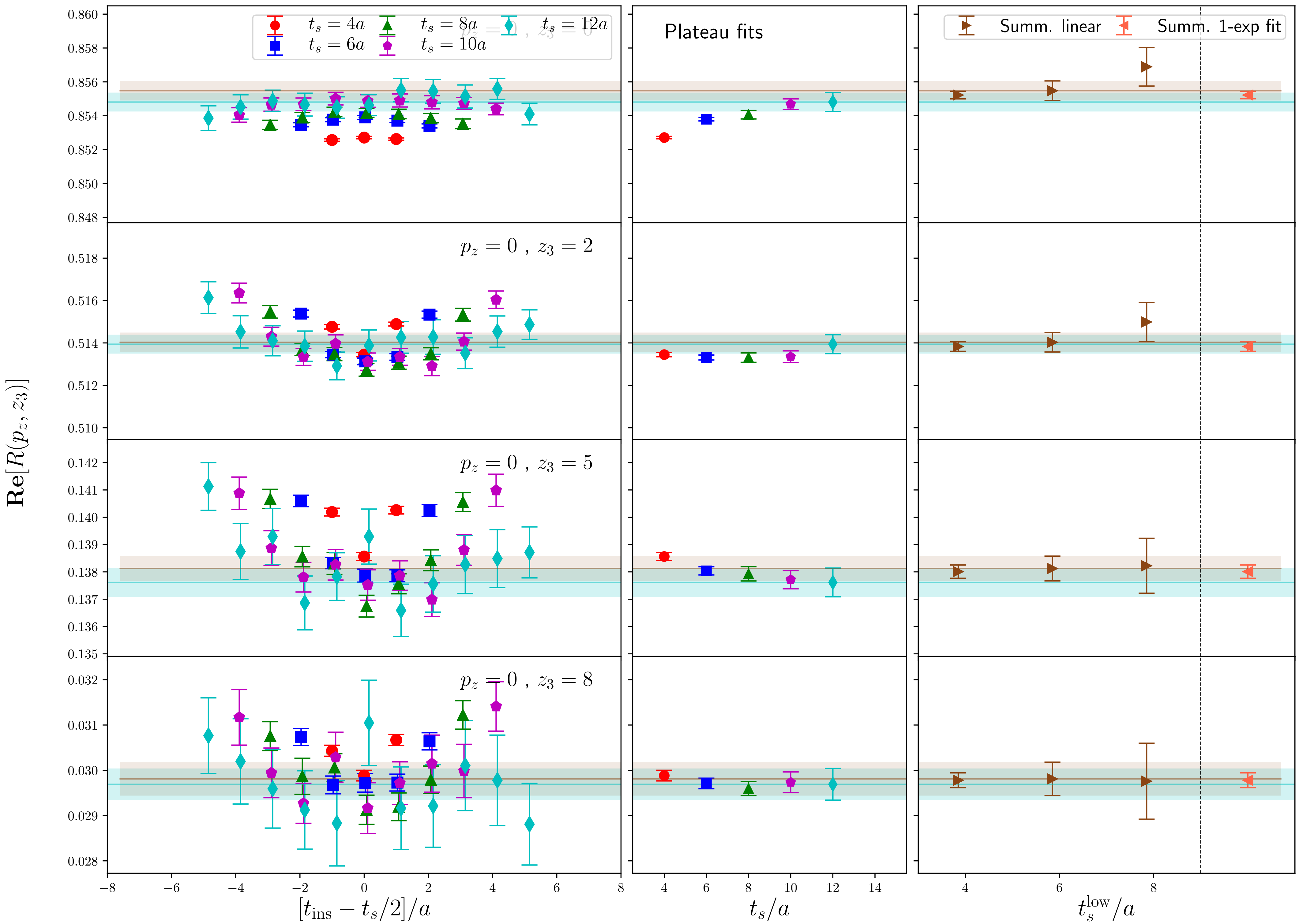


Ratio for unpolarized distribution for all streams for various (P_z, z_3) and t_{sep}



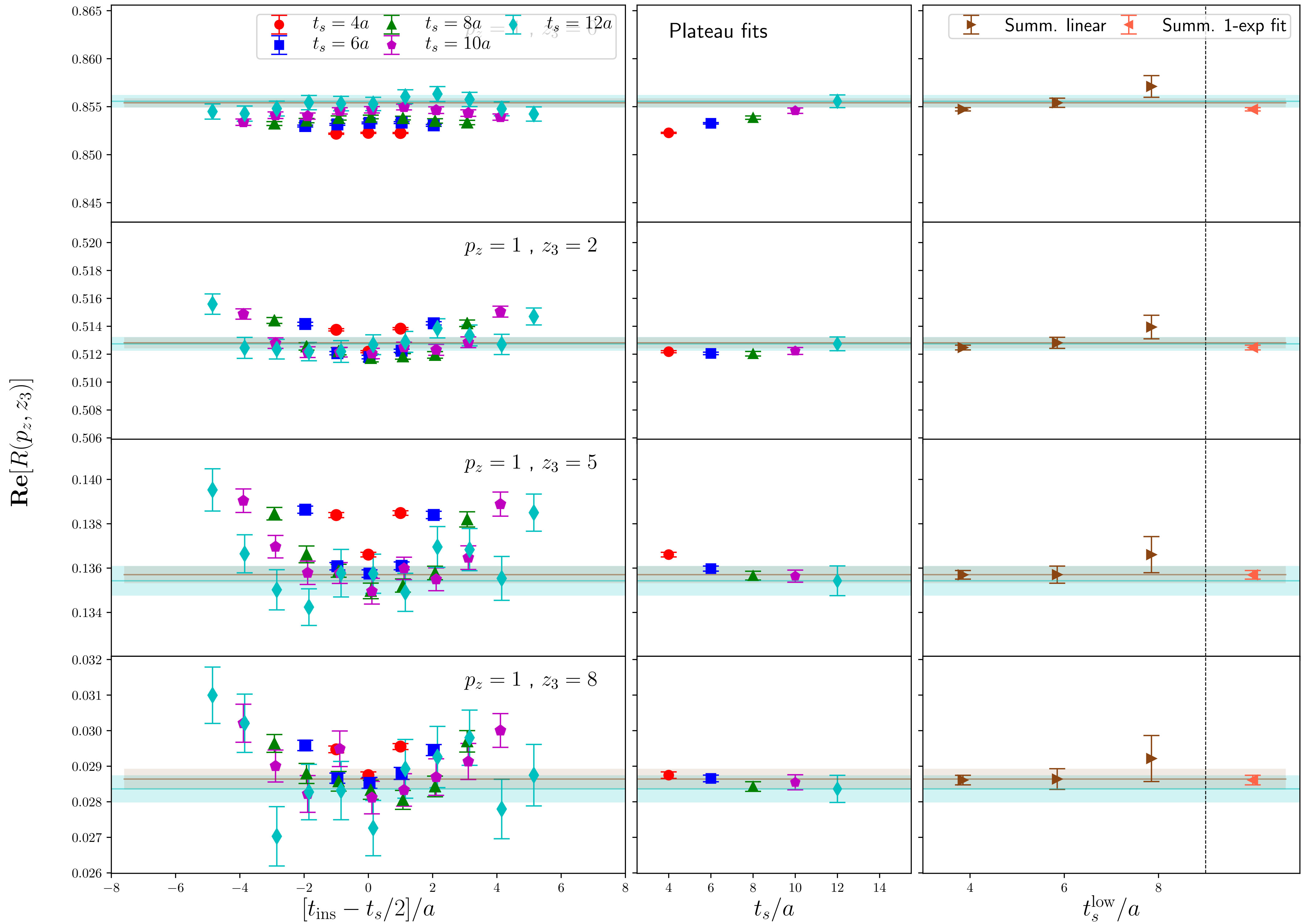
Ratio multi-plots with fits

Real part, $P_z = 0$



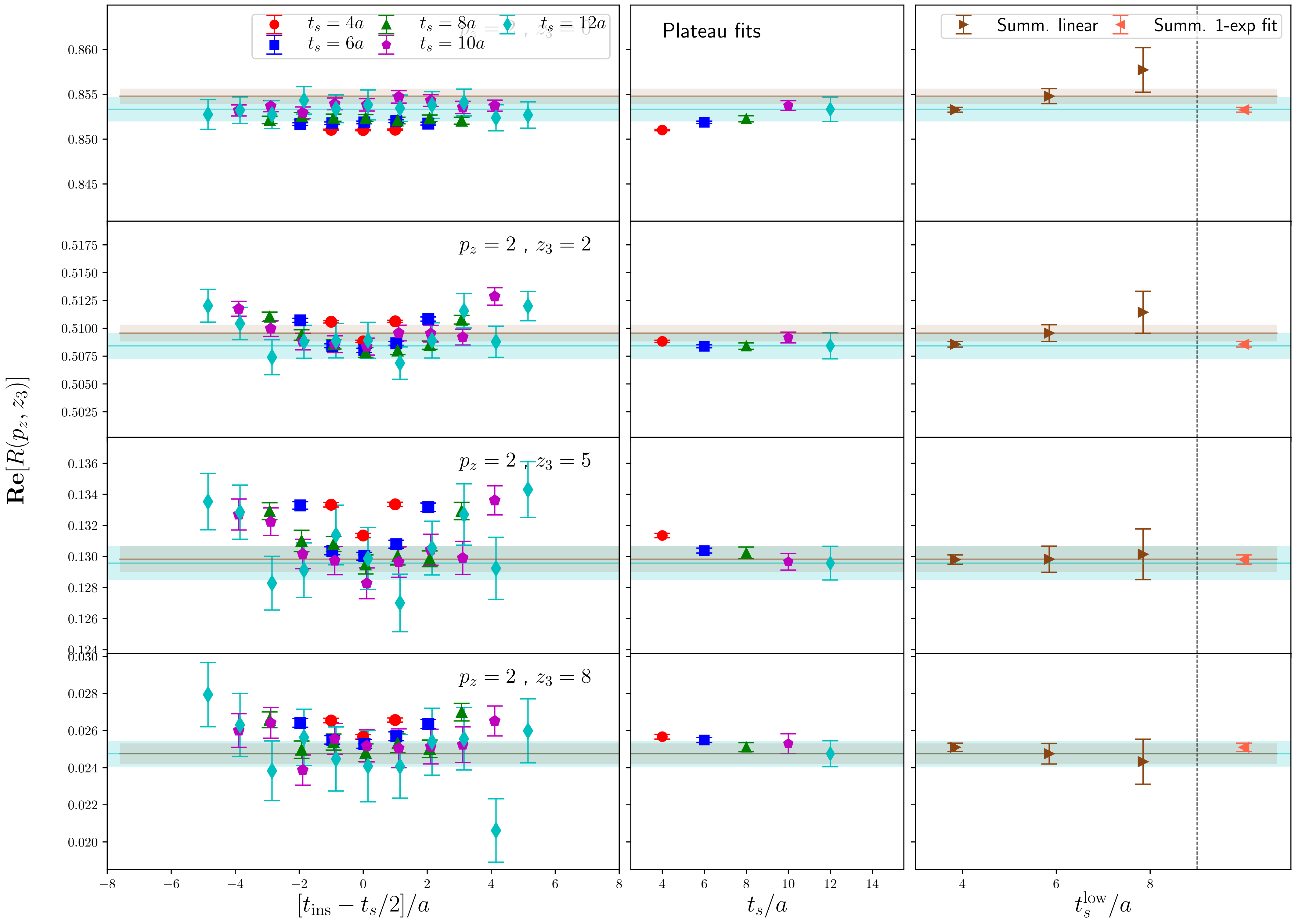
Ratio multi-plots with fits

Real part, $P_z = 1$



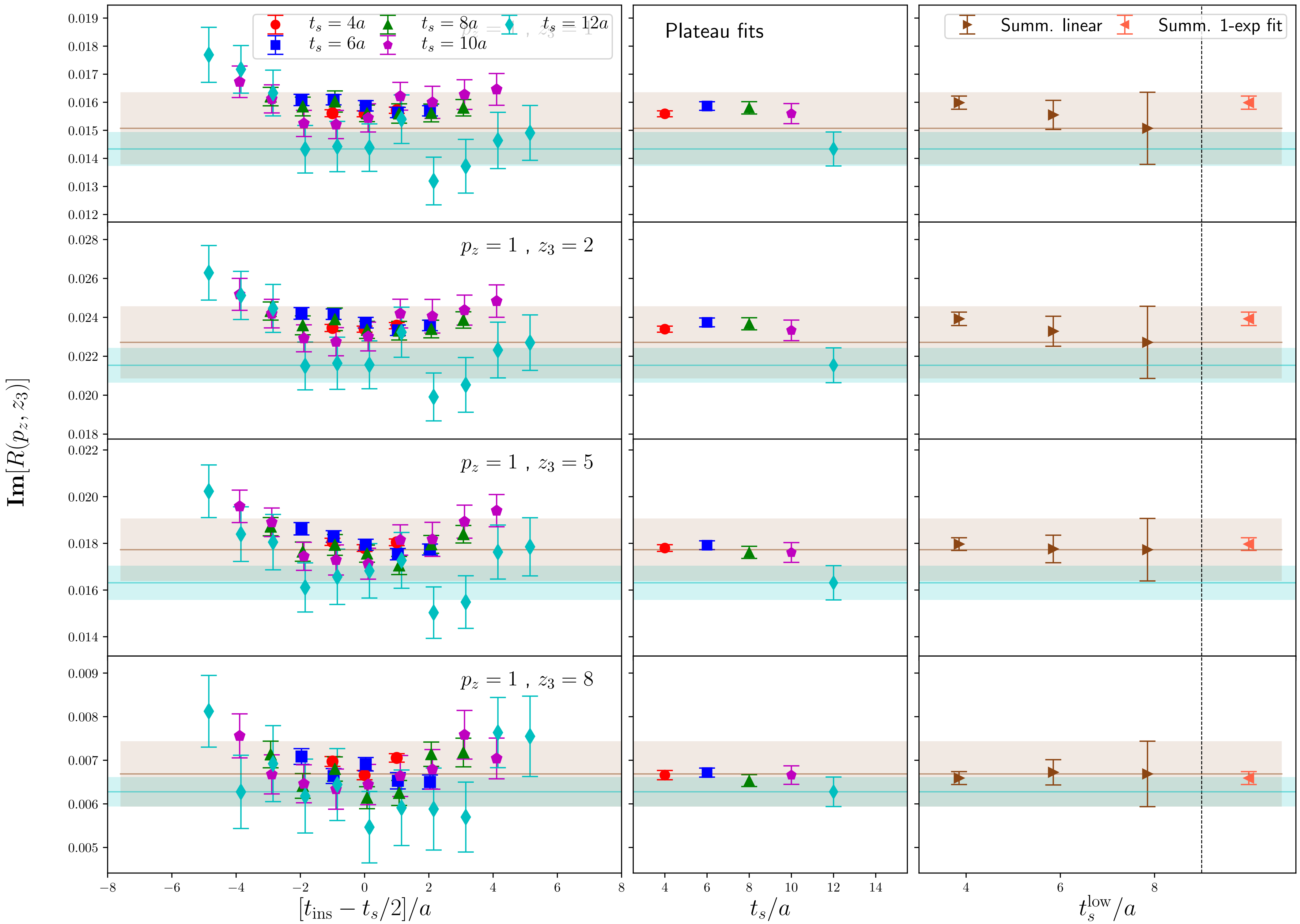
Ratio multi-plots with fits

Real part, $P_z = 2$



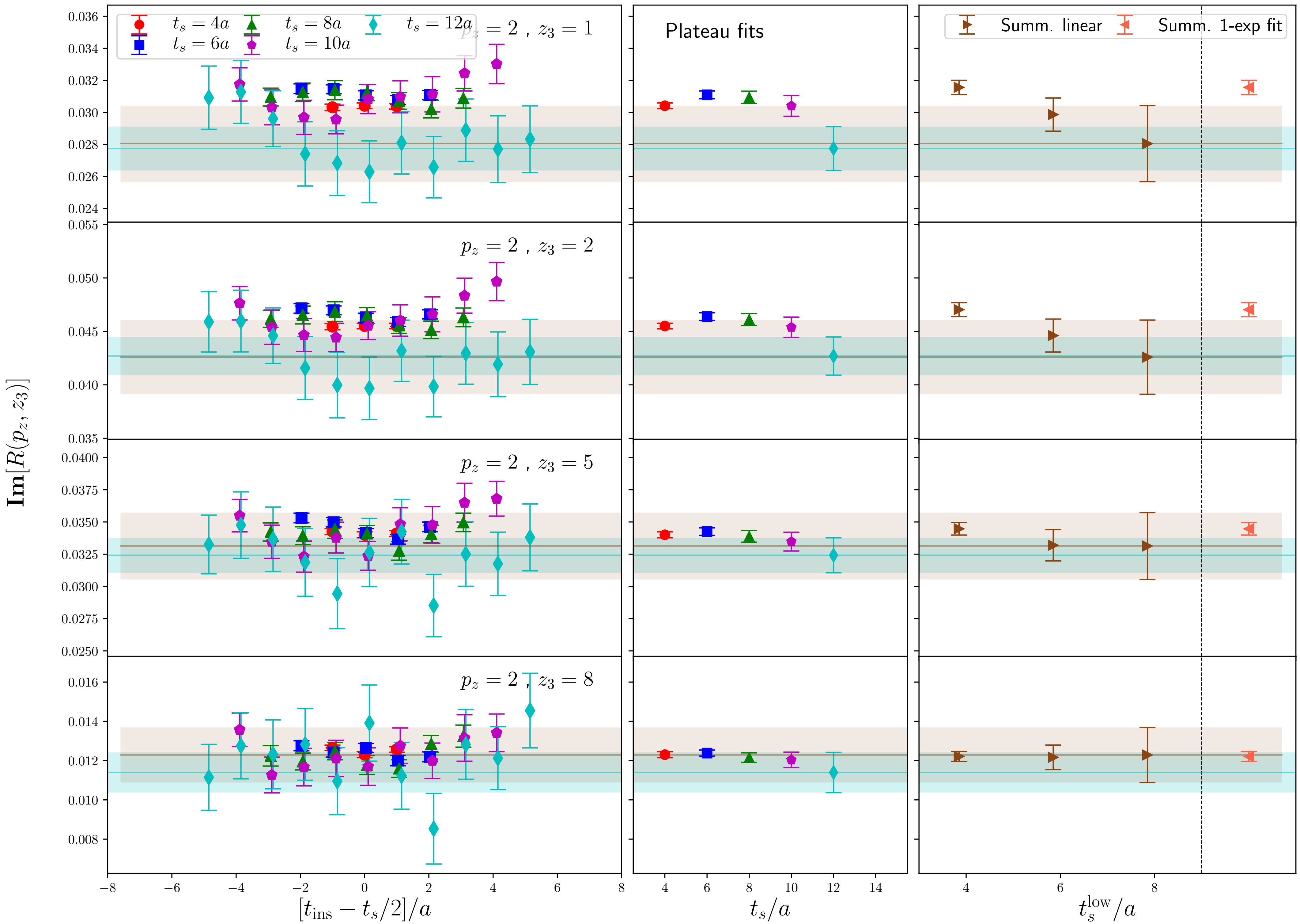
Ratio multi-plots with fits

Imag part, $P_z = 1$



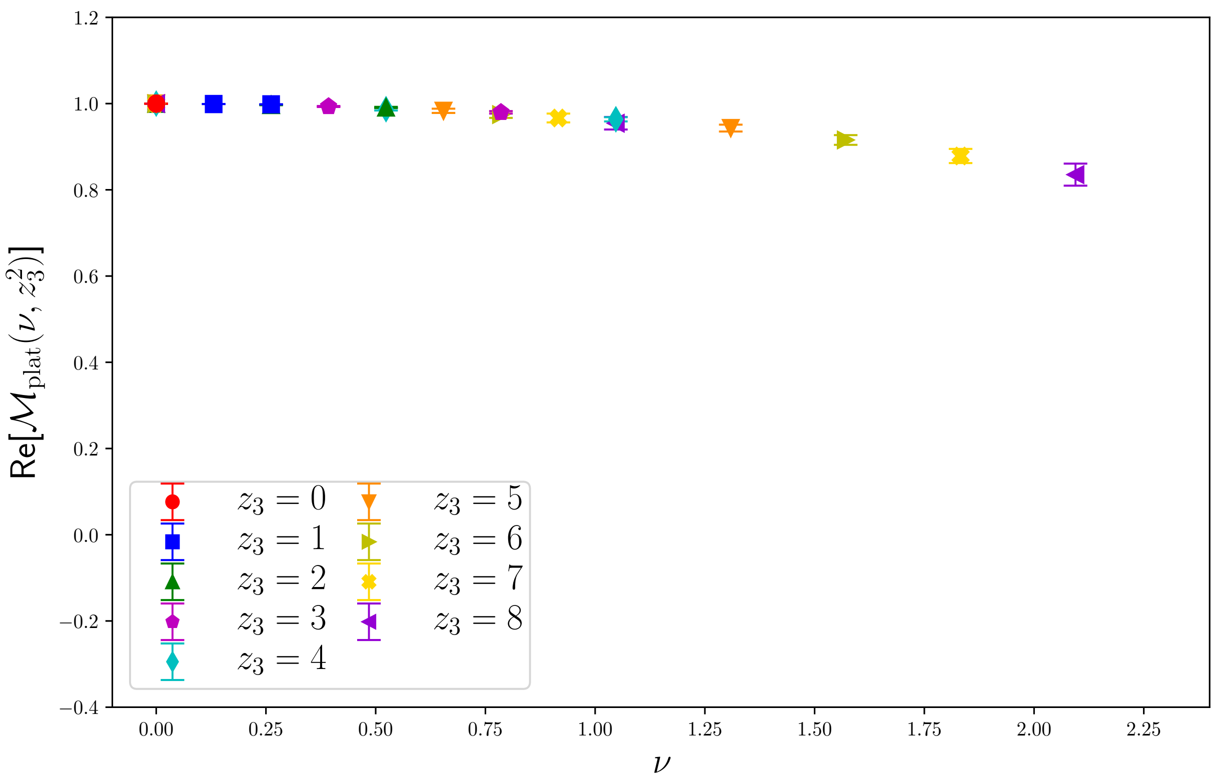
Ratio multi-plots with fits

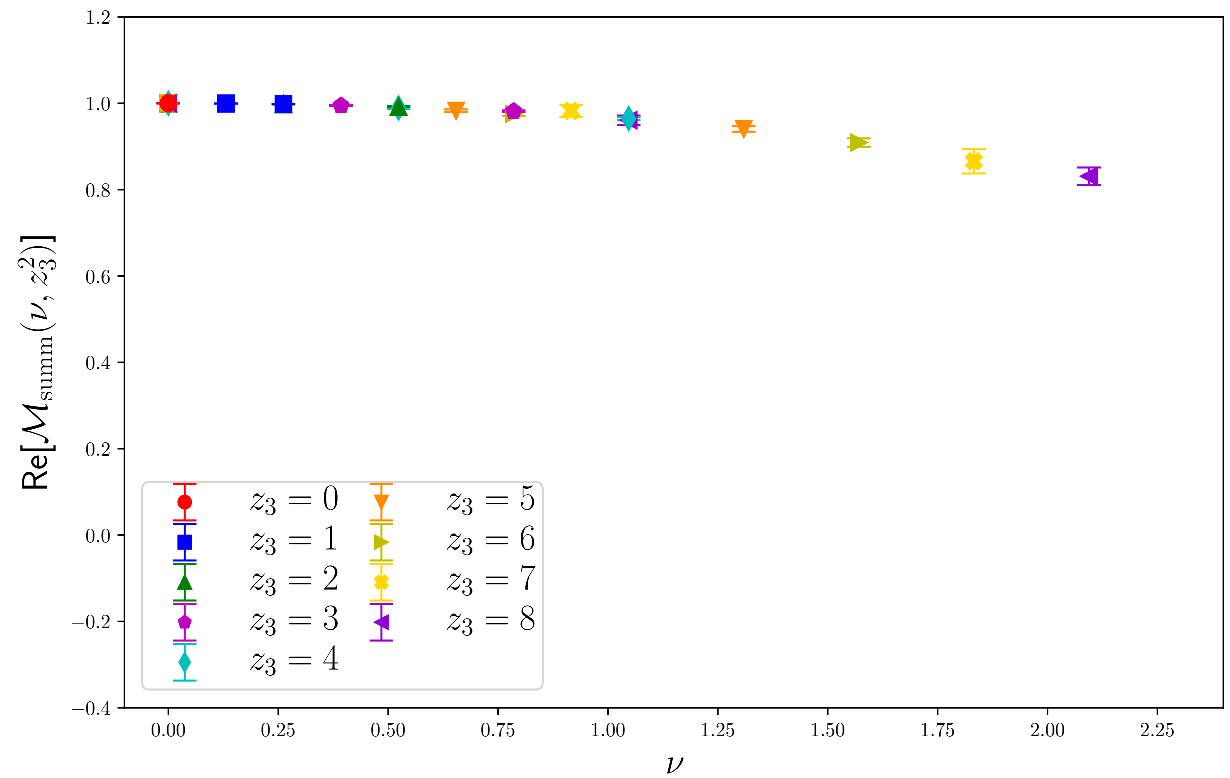
Imag part, $P_z = 2$

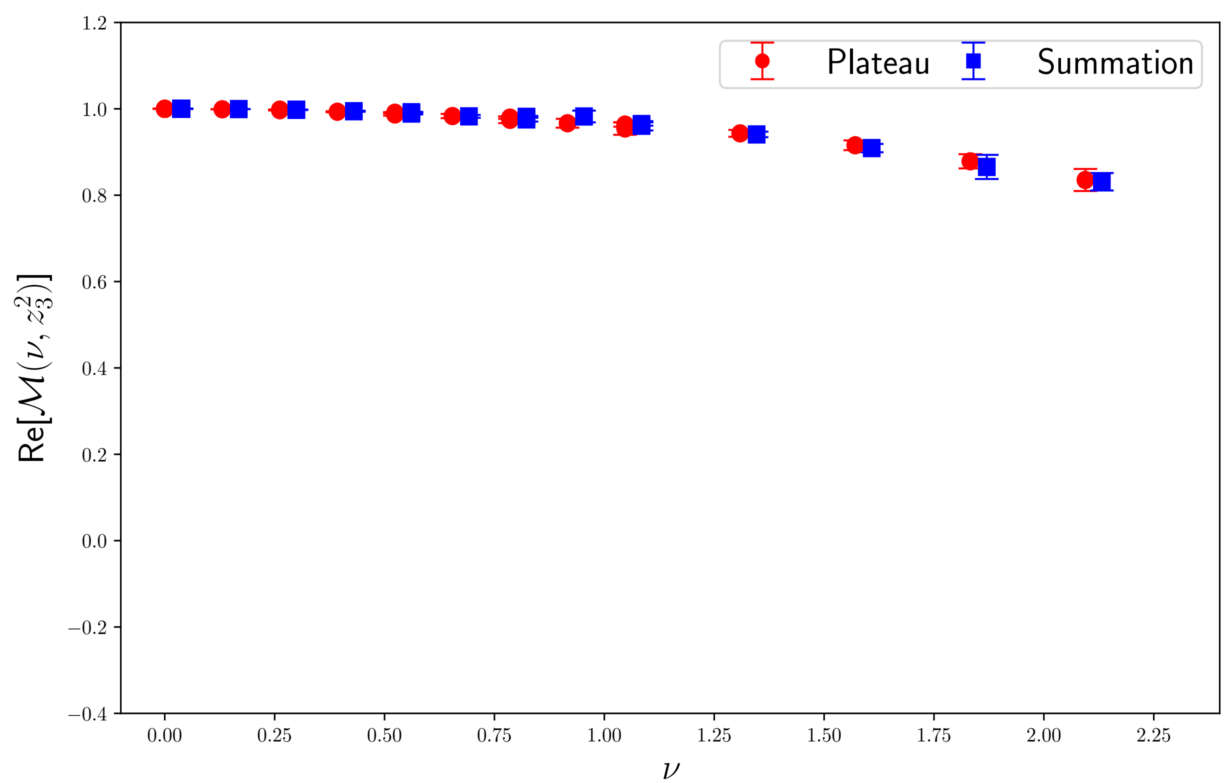


Reduced Ioffe-time distributions - Real part

Definition: $$\mathscr{M}_{\rm Re,Im}\left(\nu, z_3^2\right) \equiv \left(\frac{M_{\rm Re,Im}(\nu, z_3^2)}{M_{\rm Re}(\nu,0)\,|_{z_3=0}}\right) \times \left(\frac{M_{\rm Re}(0,0)\,|_{P_z=0,z_3=0}}{M_{\rm Re}(0,z_3^2)\,|_{P_z=0}}\right)$$

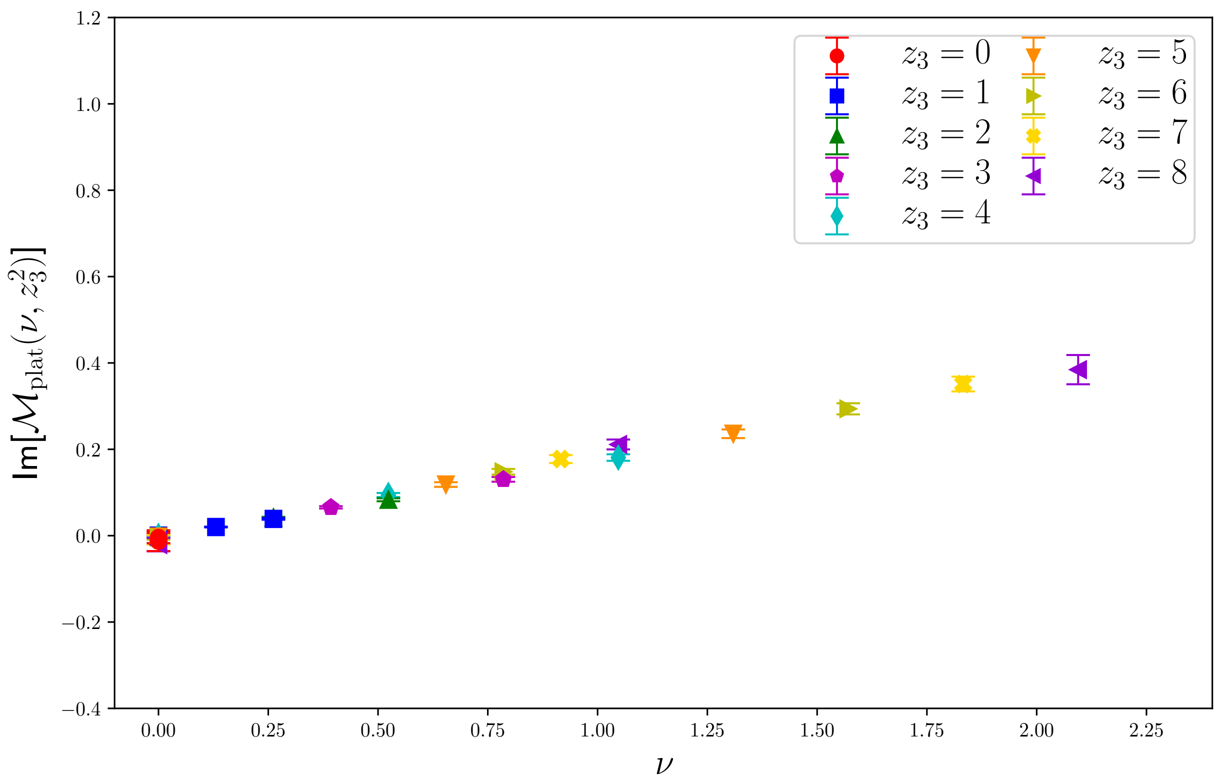


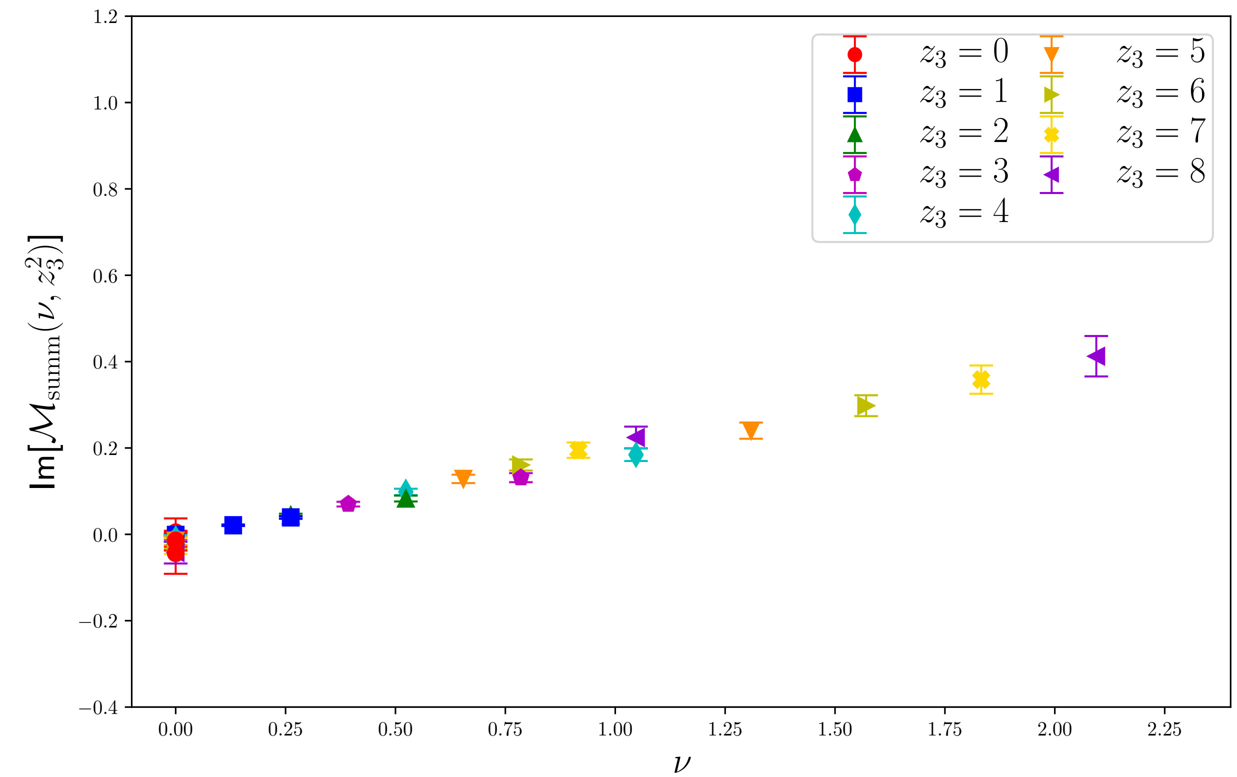


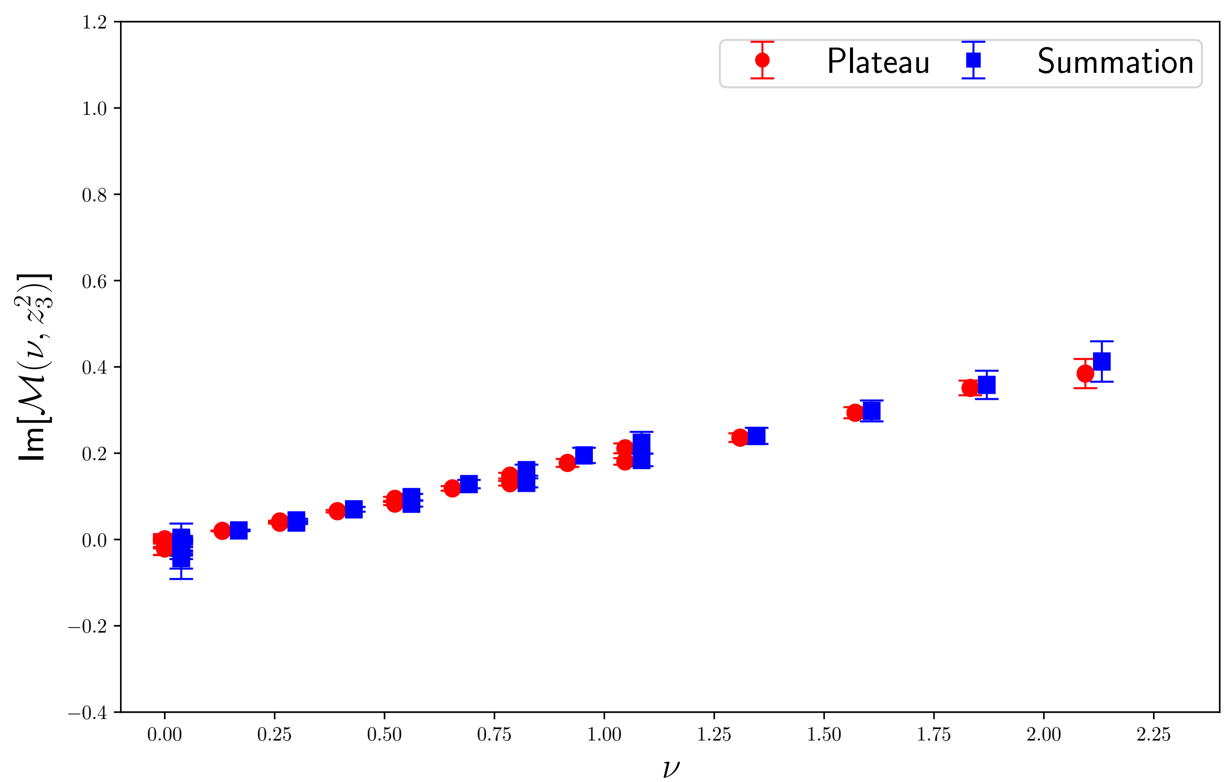


Reduced Ioffe-time distributions - Imaginary part

Definition: $$\mathscr{M}_{\text{Re,Im}}\left(\nu, z_3^2\right) \equiv \left(\frac{M_{\text{Re,Im}}(\nu, z_3^2)}{M_{\text{Re}}(\nu,0)\,|_{z_3=0}}\right) \times \left(\frac{M_{\text{Re}}(0,0)\,|_{P_z=0,z_3=0}}{M_{\text{Re}}(0,z_3^2)\,|_{P_z=0}}\right)$$

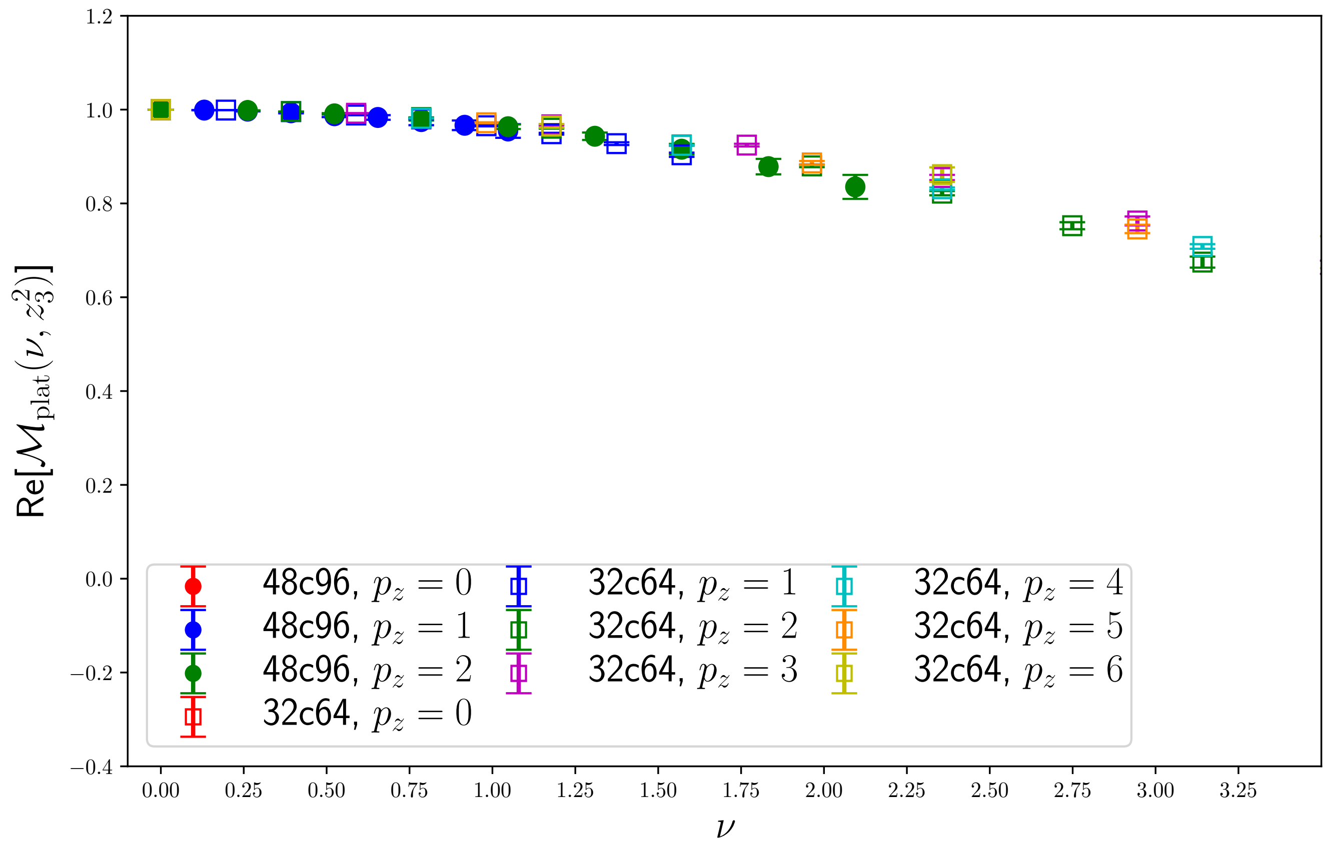


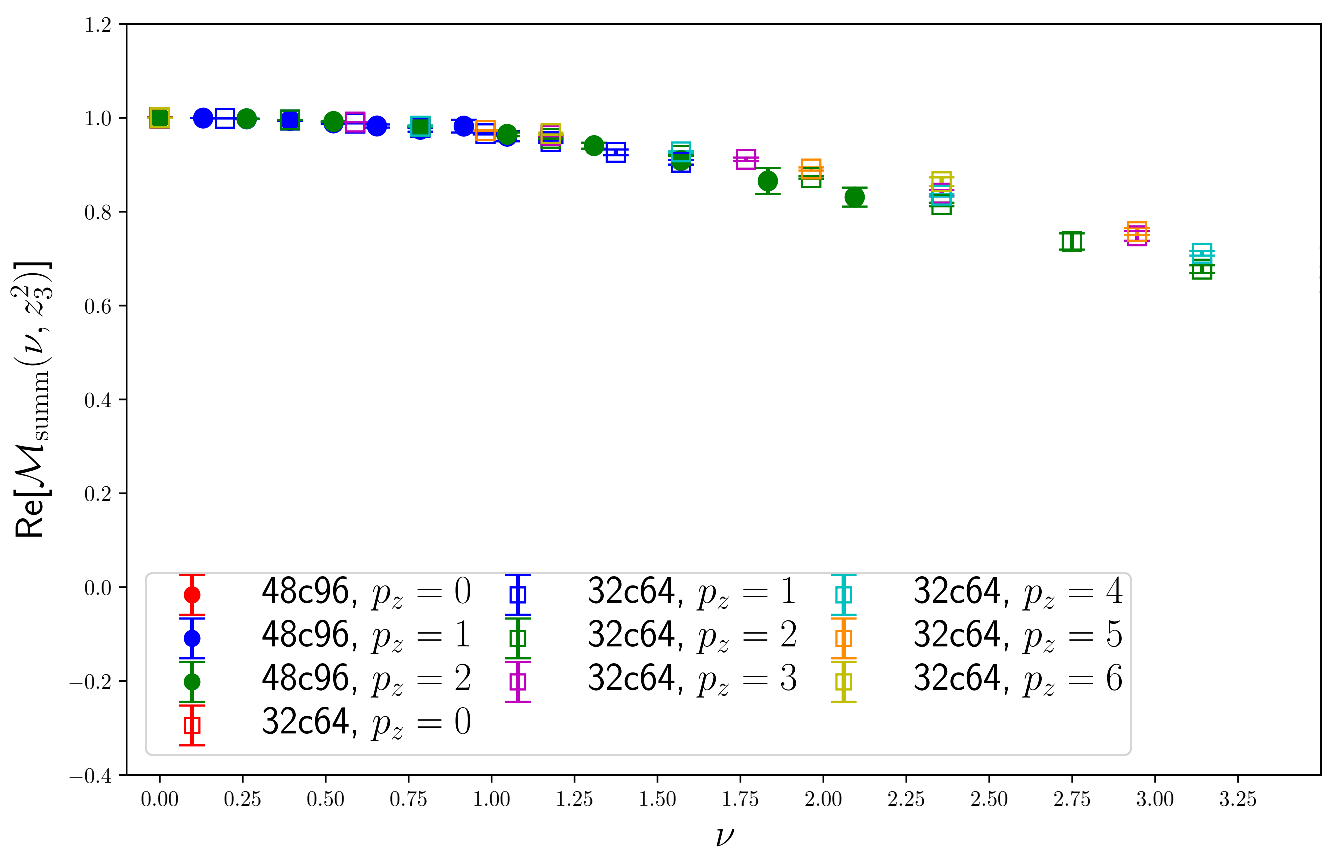




Reduced Ioffe-time distributions - Comparison across ensembles

Real part





Reduced Ioffe-time distributions - Comparison across ensembles

Imaginary part