

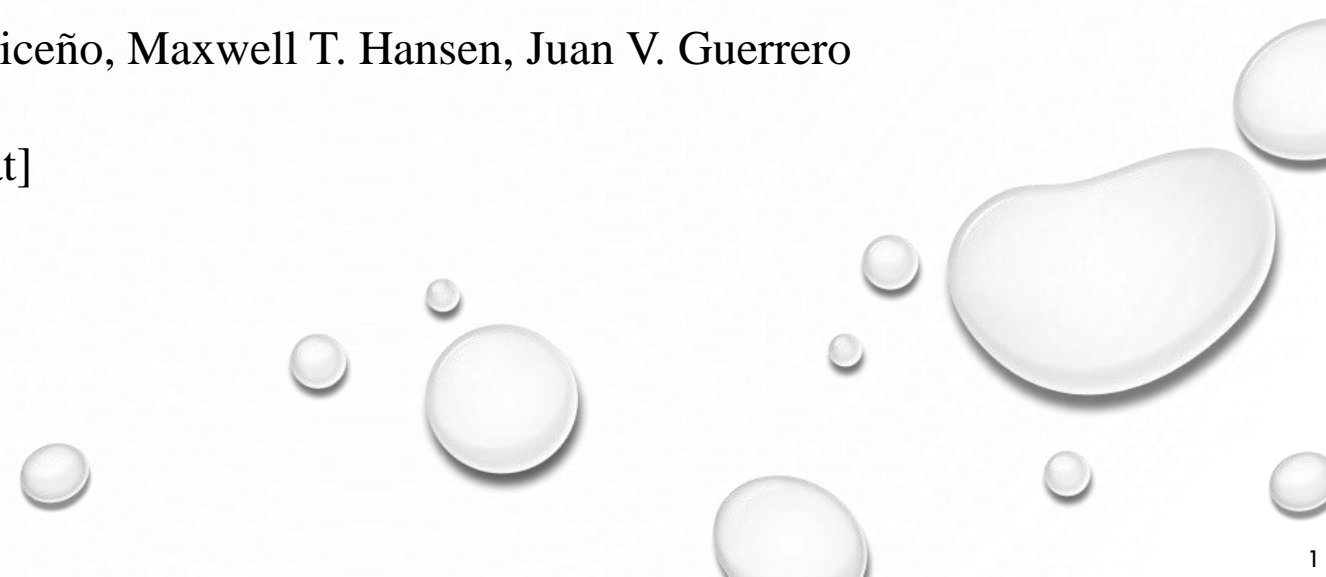


THE ROLE OF BOUNDARY CONDITIONS IN QUANTUM COMPUTATIONS OF SCATTERING OBSERVABLES

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MOTIVATION

- RECENTLY PROPOSED THAT REAL TIME CALCULATIONS MAY BE POSSIBLE THROUGH:
 - IMPROVED MONTE CARLO SAMPLING Alexandru et al. (2016)
 - QUANTUM COMPUTATIONS USQCD (2019)
- IN PRINCIPLE, COULD GIVE ACCESS TO SCATTERING OBSERVABLES FOR HIGH ENERGIES
- VOLUME TRUNCATION LEADS TO NO ASYMPTOTIC STATES
- 2 DIFFERENT POSSIBILITIES TO RESOLVE THIS:
 - LÜSCHER'S SCATTERING FORMALISM
 - DIRECTLY EXTRACT OBSERVABLES FROM ∞ -VOL. LIMIT

OBESERVABLES CONSIDERED

2 → 2 HADRONIC AMPLITUDES

$$\begin{aligned}
 i\mathcal{M} &= \text{Diagram 1} \\
 &= \text{Diagram 2} + \text{Diagram 3} + \text{Diagram 4} + \dots \\
 &= \text{Diagram 5} + \text{Diagram 6} + \text{Diagram 7} + \dots
 \end{aligned}$$

Labels: $i\mathcal{B}$, $i\mathcal{K}$, ρ

- IN 1+1D
- WITHOUT COUPLED CHANNELS

FOCUSING ON THIS

$$\mathcal{T} \equiv i \int d^2x e^{i\omega t - i\mathbf{q} \cdot \mathbf{x}}$$

$$\times \langle \mathbf{p}_f | T\{\mathcal{J}(x)\mathcal{J}'(0)\} | \mathbf{p}_i \rangle_c$$

$$\begin{aligned}
 i\mathcal{T} &= \text{Diagram 1} \\
 &= \text{Diagram 2} + \text{Diagram 3} + \text{Diagram 4} + \dots \\
 &= \text{Diagram 5} + \text{Diagram 6} + \text{Diagram 7} + \dots
 \end{aligned}$$

Labels: q , $p_f + q - p_i$, p_f , p_i , $i\mathcal{T}$, $i\mathcal{H}$, ρ

1+ \mathcal{J} → 1+ \mathcal{J} COMPTON-LIKE AMPLITUDES

FINITE-VOLUME FORMALISM

$$\begin{aligned}
 i\mathcal{T}_L &= \text{tree} + \text{1-loop} + \text{2-loop} + \dots \\
 &= \text{tree} + \text{1-loop} + \text{2-loop} + \dots
 \end{aligned}$$

The diagram shows two rows of Feynman diagrams. The first row shows a tree-level diagram, a one-loop diagram with a vertex v , and a two-loop diagram with two vertices v . The second row shows the same diagrams but with black dots on the external lines. Arrows point from boxes labeled $i\mathcal{T}$, $i\mathcal{H}$, and iF to these dots.

Christ et al. (2015)

Briceño, Davoudi, Hansen, Schindler, Baroni (2020)

$$\mathcal{T}_L = \mathcal{T} - \mathcal{H} \frac{1}{F^{-1} + \mathcal{M}} \mathcal{H}'$$

$$F(E^*, \mathbf{P}, L) = \frac{1}{2} \left[\frac{1}{L} \sum_n - \int \frac{dk}{2\pi} \right] \frac{1}{2\omega_k} \frac{1}{(P - k)^2 - m^2 + i\epsilon}$$

GIVES A METHOD TO
EXTRACT \mathcal{T} FROM FINITE-
VOLUME INFORMATION

AN UNEXPECTED APPLICATION

USE \mathcal{T}_L TO PREDICT VOLUME EFFECTS IN
MINKOWSKI OBSERVABLES

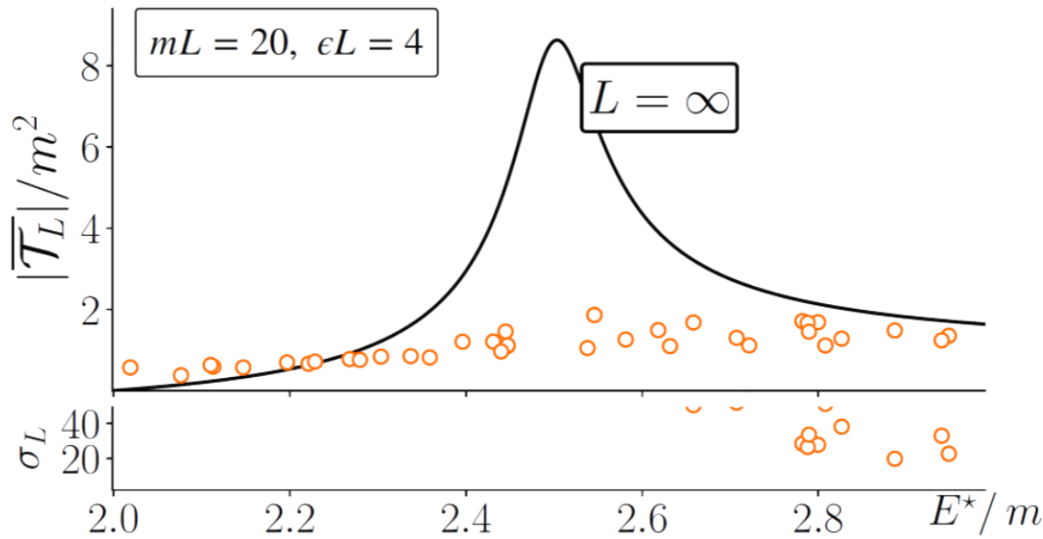
IDENTIFY VALUES OF ϵ AND L THAT GIVE AN
ESTIMATE OF THE LIMIT

$$\lim_{\epsilon \rightarrow 0} \lim_{L \rightarrow \infty} \mathcal{T}_L(p_f, q, p_i) = \mathcal{T}(E^*, Q^2, Q_{if}^2)$$

$$E \rightarrow E + i\epsilon$$

NON-PERTURBATIVE, MODEL INDEPENDENT APPROACH!

NUMERICAL RESULTS



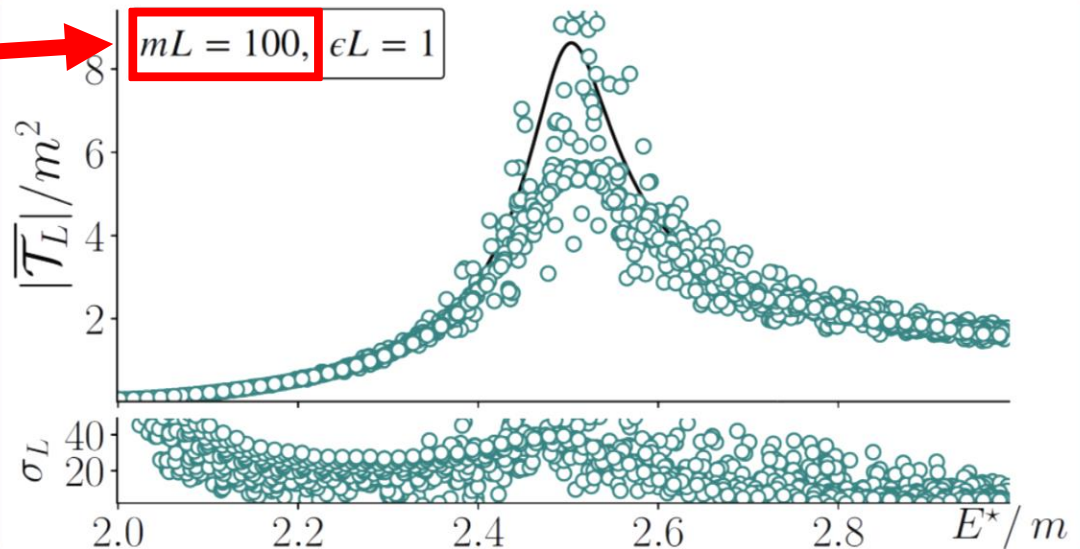
$$\mathcal{T}_L = \mathcal{T} - \mathcal{H} \frac{1}{F^{-1} + \mathcal{M}} \mathcal{H}'$$

$\sigma_L = \% \text{ DIFFERENCE}$

OUCH!

ENHANCED
VOLUME
EFFECTS

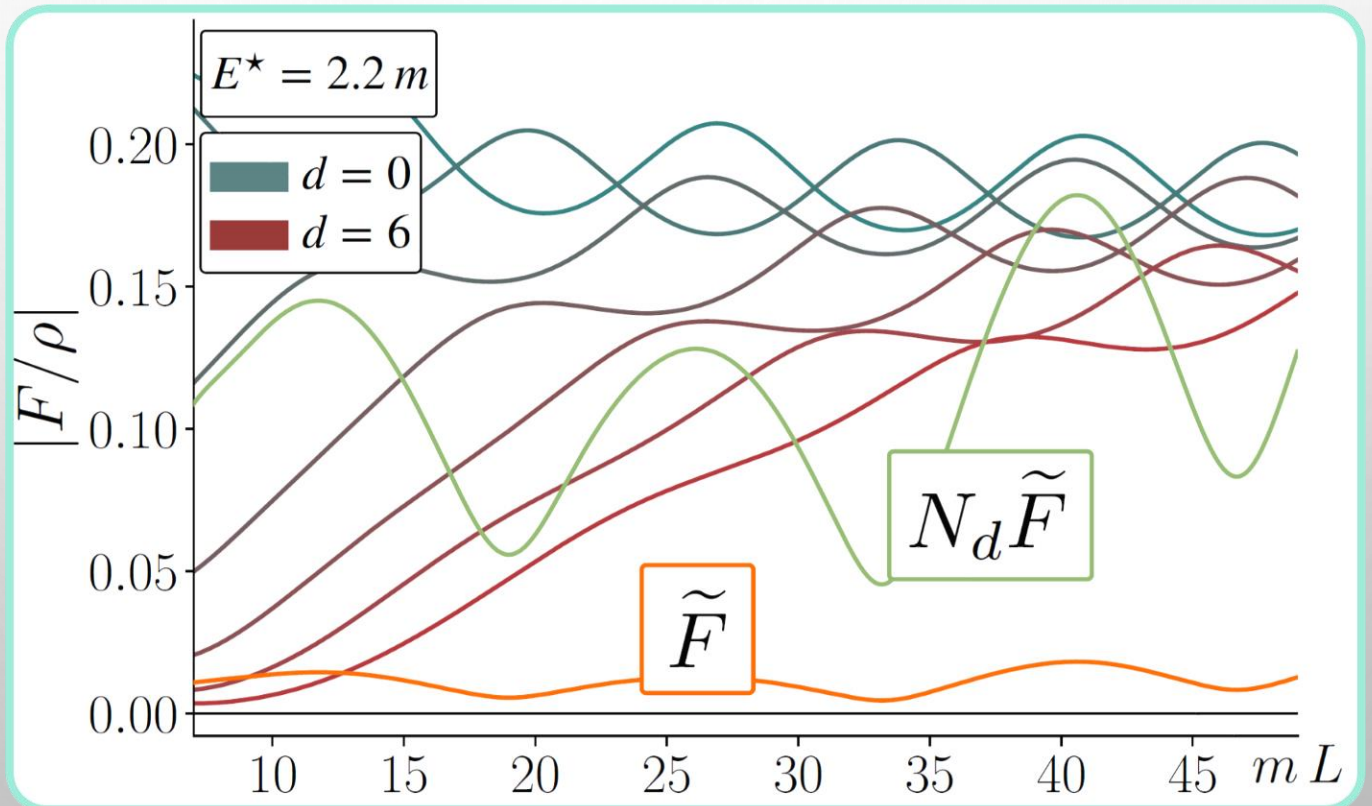
FIS TOO
LARGE



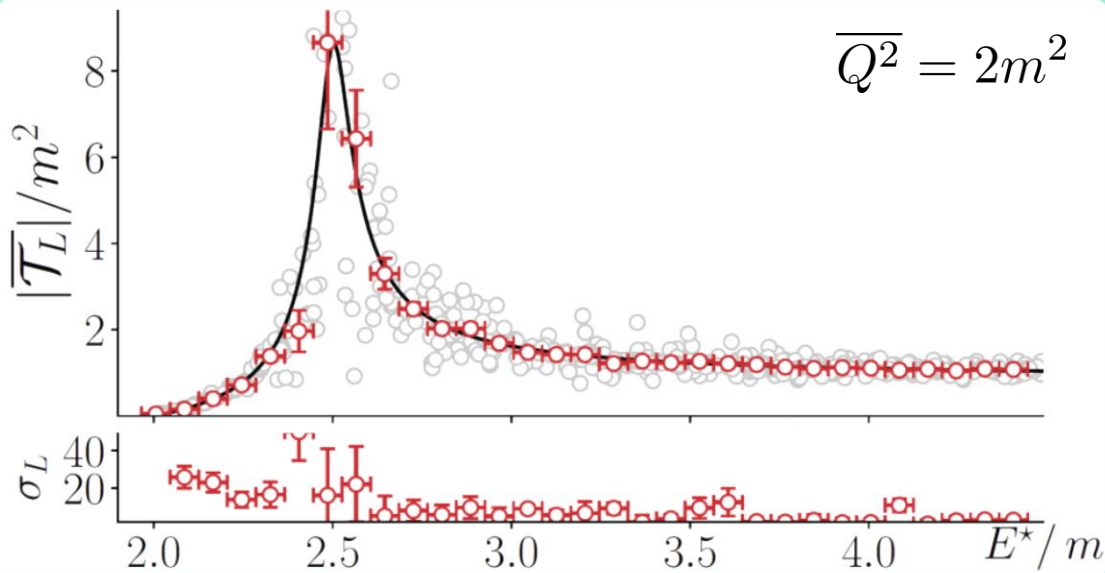
FINITE-VOLUME DISTORTIONS

$$F(E^*, \mathbf{P}, L) = \frac{1}{2} \left[\frac{1}{L} \sum_n - \int \frac{dk}{2\pi} \right] \frac{1}{2\omega_k} \frac{1}{(P - k)^2 - m^2 + i\epsilon}$$

$$P = \frac{2\pi d}{L}$$



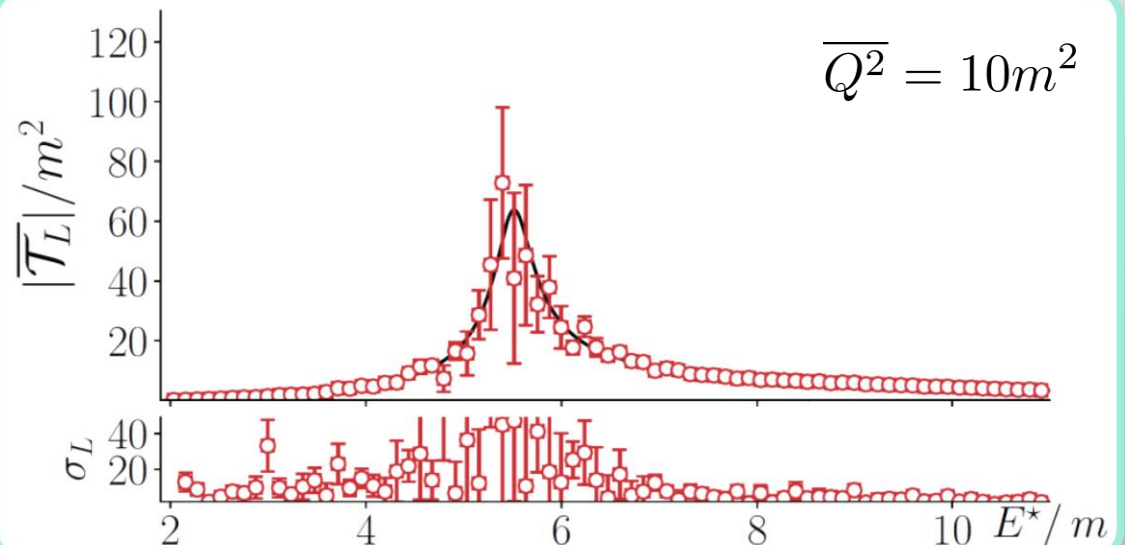
AVERAGING TECHNIQUE



VARYING P
CHANGES \mathcal{T}_L BUT
NOT \mathcal{T}

AVERAGED OVER
 $mL = 20, 25, 30$

BINNED OVER
REDUNDANT
KINEMATICS



SUMMARY

- WE HAVE EXPLORED THE POSSIBILITY OF EXTRACTING SCATTERING AMPLITUDES FROM FINITE-VOLUME MINKOSWSKI CORRELATION FUNCTIONS
- FOCUS: COMPTON-LIKE AMPLITUDES
- NAÏVE ANALYSIS SHOW THAT ONE NEEDS VOLUMES OF $mL \approx \mathcal{O}(100)$ TO RECOVER INFINITE VOLUME AMPLITUDE
- BINNING: VOLUMES OF $mL \approx 20 - 30$ ALLOW TO RECOVER AMPLITUDE