nucl-th/0009003

Quantum corrections for pion correlations involving resonance decays

Motivation:

Resonances alter pion correlations

- G. F. Bertsch, et al., Phys. Rev. **C49**, 442 (1994)
- R. Lednicky and T. B. Progulova, Z. Phys. **C55**, 295 (1992)

Goals:

- Determine quantitatively the importance of quantum propagation
- Incorporate quantum corrections into semi-classical transport models

Correlation Function: The Basics

Definition:

$$C(\mathbf{p}_1,\mathbf{p}_2) \equiv \frac{P_2(p_1,p_2)}{P_1(p_1)P_1(p_2)} \ , \qquad P(p) = \sum_f \left| \int d^4x \ T_f(x) e^{ip\cdot x} \right|^2$$

Source Function:

$$S(p,x) \equiv \sum_f \int d^4\delta x \ T_f^*(x+\delta x/2) T_f(x-\delta x/2) e^{-ip\cdot\delta x}$$

$$C(\mathbf{p}_1,\mathbf{p}_2) = 1 + \frac{\sum_{a,b} \int d^4x_a d^4x_b \ S_a(\bar{p},x_a) \, S_b(\bar{p},x_b) \, e^{i(p_2-p_1)\cdot(x_a-x_b)}}{\sum_{a,b} \int d^4x_a d^4x_b \ S_a(p_1,x_a) S_b(p_2,x_b)}$$

Simplify with

$$I(p_1,p_2) = \int d^4x \ S(\bar{p},x) \, e^{i(p_2-p_1)\cdot x} \ , \qquad \bar{p} = \frac{p_1+p_2}{2}$$

$$C(\mathbf{p}_1,\mathbf{p}_2) = 1 + \frac{\sum_{a,b} I_a(p_1,p_2) I_b(p_2,p_1)}{\sum_{a,b} I_a(p_1,p_1) I_b(p_2,p_2)}$$

Pion Correlation Function for $A \longrightarrow \pi\pi$

Amplitude for pion production:

$$T_{\pi,f_A,k}(x) = g \int d^4x_A \; \tilde{G}_A(x - x_A) T_{A,f_A}(x_A) e^{ik\cdot x}$$

$$I_A(p_1,p_2) = g^2 \int \frac{d^3k}{2E_k} \int d^4x_A \; e^{i(p_2-p_1)\cdot x_A} S_A\left(\frac{p_1+p_2}{2}+k, x_A\right) \times G_A(p_1+k) G_A^*(p_2+k)$$

where

$$G_A(p) = \frac{i}{p^2 - M_A^2 + i\Pi_A(p^2)} \;, \quad \Pi_A(m^2) = M_A \Gamma_A \frac{q}{q_R} \frac{M_A}{m}.$$

Smoothness Approximation

$$S_a\left(\frac{p_1+p_2}{2}, x_a\right) S_b\left(\frac{p_1+p_2}{2}, x_b\right) \longrightarrow S_a(p_1, x_a)\, S_b(p_2, x_b)\,.$$

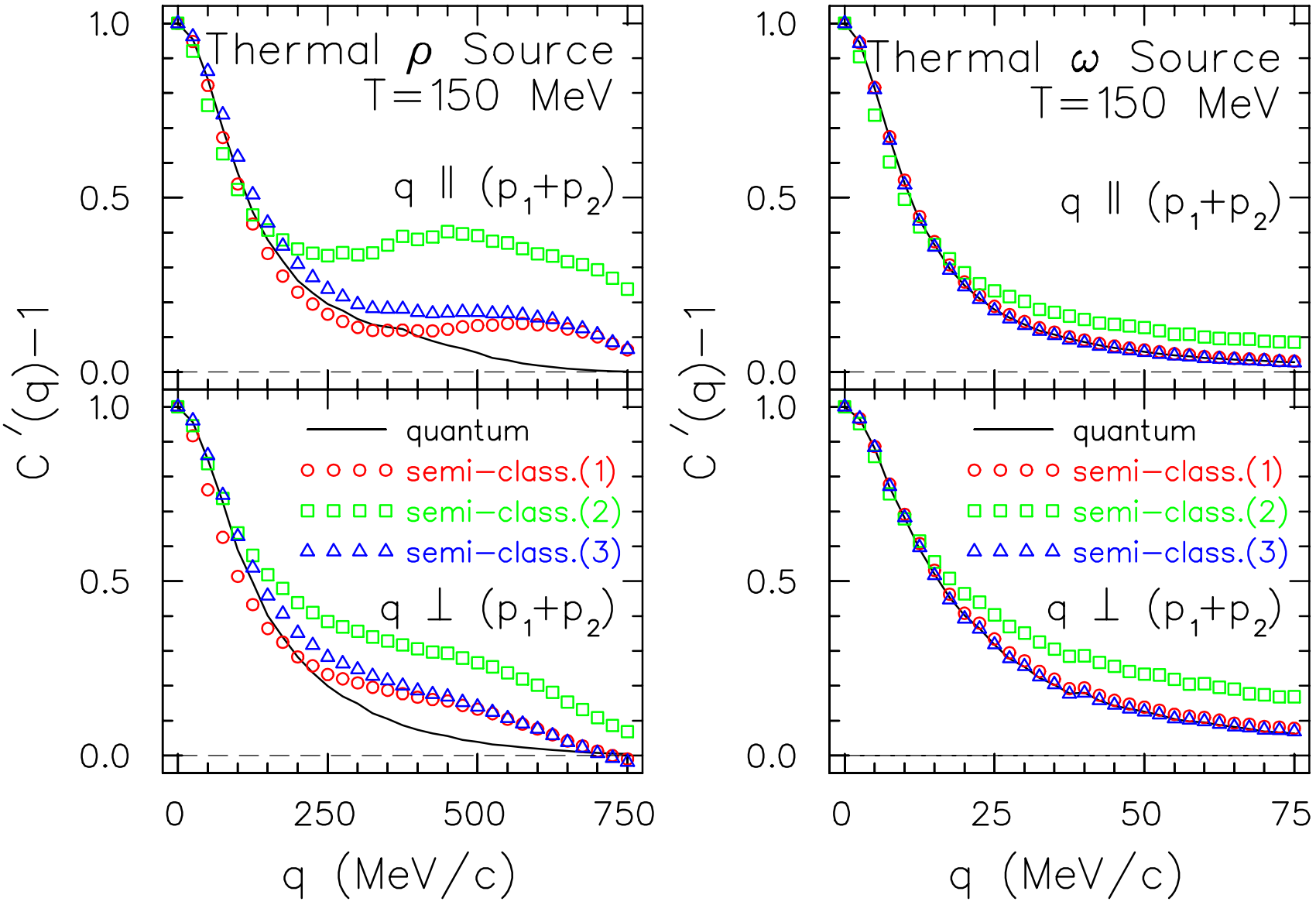
I_A can be calculated in classical models (no reference to x_π!).

Semi-Classical Correlation for $A \longrightarrow \pi\pi$

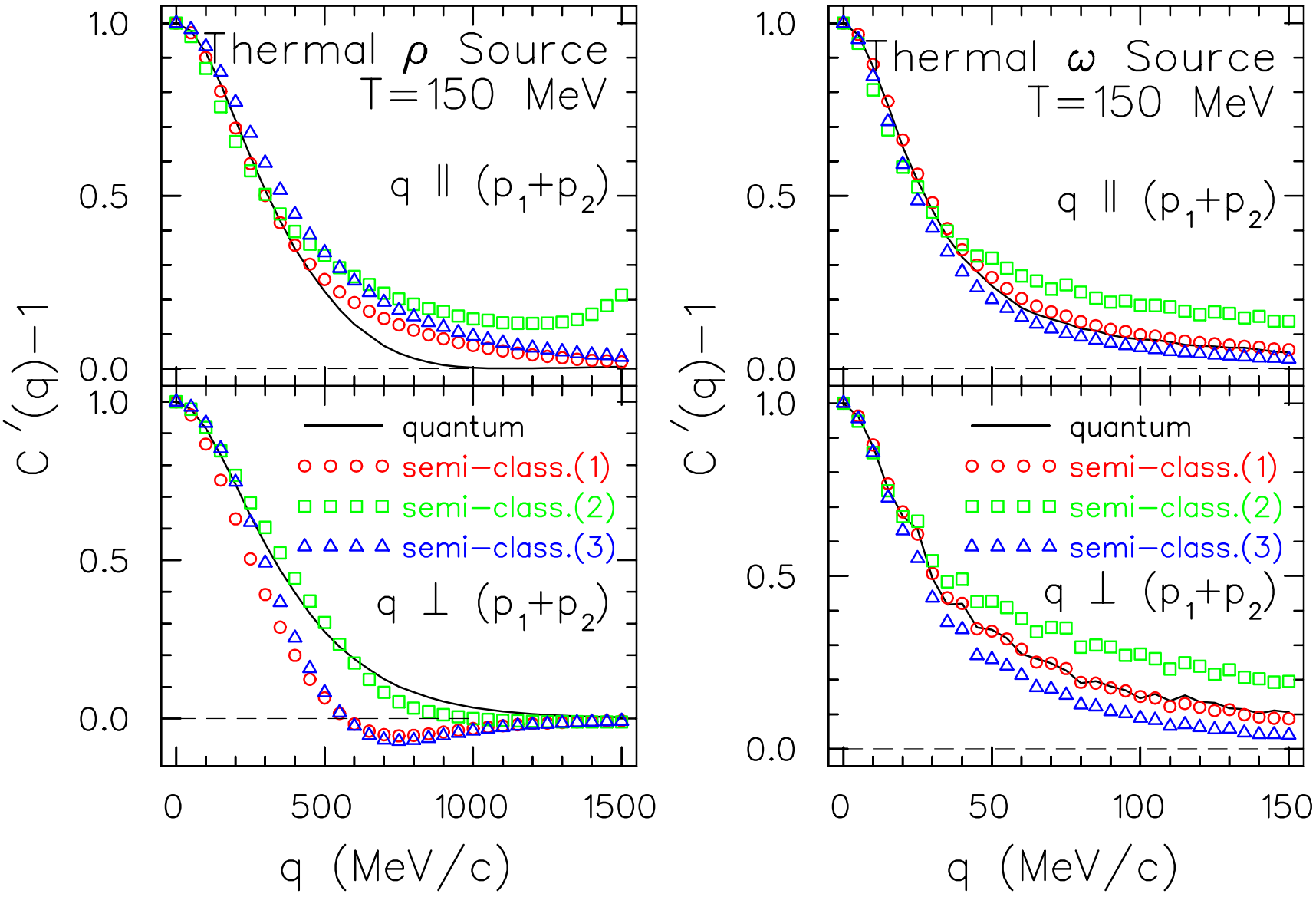
$$I_A(p,p) = \int \frac{d^3k}{2E_k} \int d^4x_A \int d^4(\delta x)\ S_A\left(p+k, x_A\right) e^{i(p_2-p_1)\cdot(x_A+\delta x)}$$
$$\times \delta^3\left(\delta\mathbf{x} - \mathbf{v}_A\delta t\right) \frac{1}{\gamma_A\tau} e^{-\delta t/(\gamma_A\tau)} \Theta(\delta t)$$

1. $\Gamma = \Gamma(m^2)$
2. $1/\Gamma = \frac{\partial\delta}{\partial E}$
3. $\Gamma = const$

For $\bar{p} = 200\text{MeV}$



For $\bar{p} = 800\text{MeV}$



Why/ When does it make a difference?

Narrow Breit-Wigner resonance:

$$G_A(p) = \frac{1}{2M_A p_0 - E_p + i\Gamma/2}\frac{i}{}$$

Probability distribution for resonance decay:

$$\mathcal{R}(\Delta E, t) = \frac{\Gamma}{\pi}\Theta(t)e^{-\Gamma t}\frac{\sin(2\Delta E t)}{\Delta E}$$

where $\Delta E = E_k + E_p - M_A$.

Moments of the Probability distribution:

$$\langle t\rangle = \frac{\int dt\ t\ \mathcal{R}(\Delta E, t)}{\int dt\ \mathcal{R}(\Delta E, t)} = \frac{\Gamma/2}{\Delta E^2 + (\Gamma/2)^2}$$

$$\langle t^2\rangle = \frac{1}{8}\frac{3\Gamma^2 - 4\Delta E^2}{\left(\Delta E^2 + \Gamma^2/4\right)^2} \neq 2\langle t\rangle^2$$