Chiral Polarization Scale at Finite Temperature

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Outline

- Motivation
- Local chirality
- Dynamical polarization
- Chiral polarization scale
- Numerical results
- Conclusions

Local chirality

- Low-lying eigenmodes of the Dirac operator play an important role in chiral symmetry breaking

$$i\not{D}\psi = \lambda\psi \quad \psi_R = \frac{1}{2}(1+\gamma_5)\psi \quad \psi_L = \frac{1}{2}(1-\gamma_5)\psi$$

- The free-field modes are unpolarized

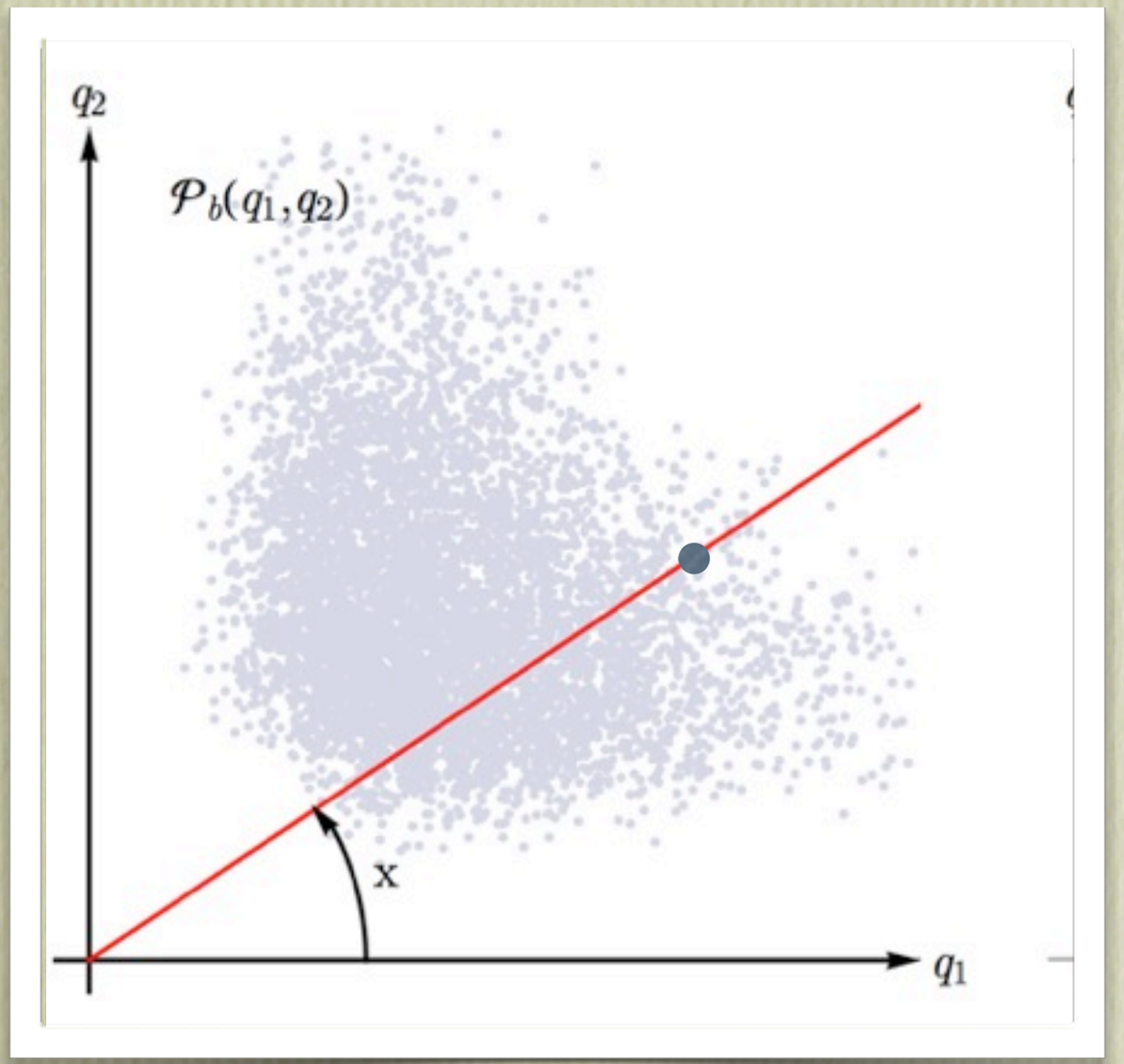
$$\langle\psi|\gamma_5|\psi\rangle = 0 \quad \Rightarrow \quad \psi(x)^\dagger\gamma_5\psi(x) = \psi_R^\dagger\psi_R - \psi_L^\dagger\psi_L = 0$$

- Eigenmodes for self-dual fields are expected to be polarized

$$\left[-D^2 + \tfrac{1}{2}\sigma_{\mu\nu}F^S_{\mu\nu}\right]\psi_L = \lambda^2\psi_L \quad F^S = \tfrac{1}{2}(F+\tilde{F})$$

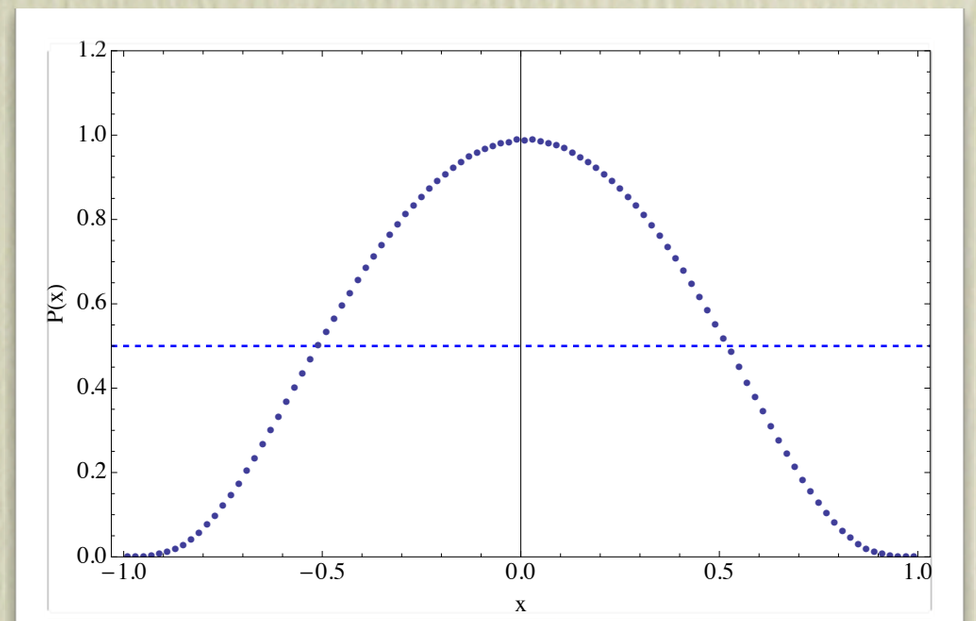
$$\left[-D^2 + \tfrac{1}{2}\sigma_{\mu\nu}F^A_{\mu\nu}\right]\psi_R = \lambda^2\psi_R \quad F^A = \tfrac{1}{2}(F-\tilde{F})$$

Dynamical polarization



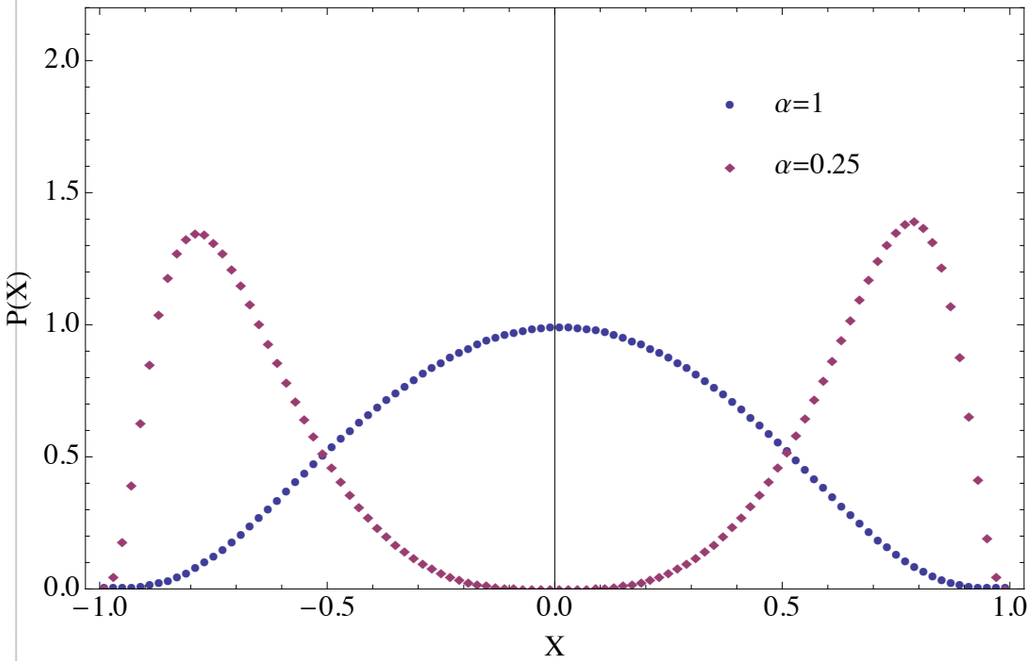
$$Q_1 = \|\psi_R\| \quad Q_2 = \|\psi_L\|$$

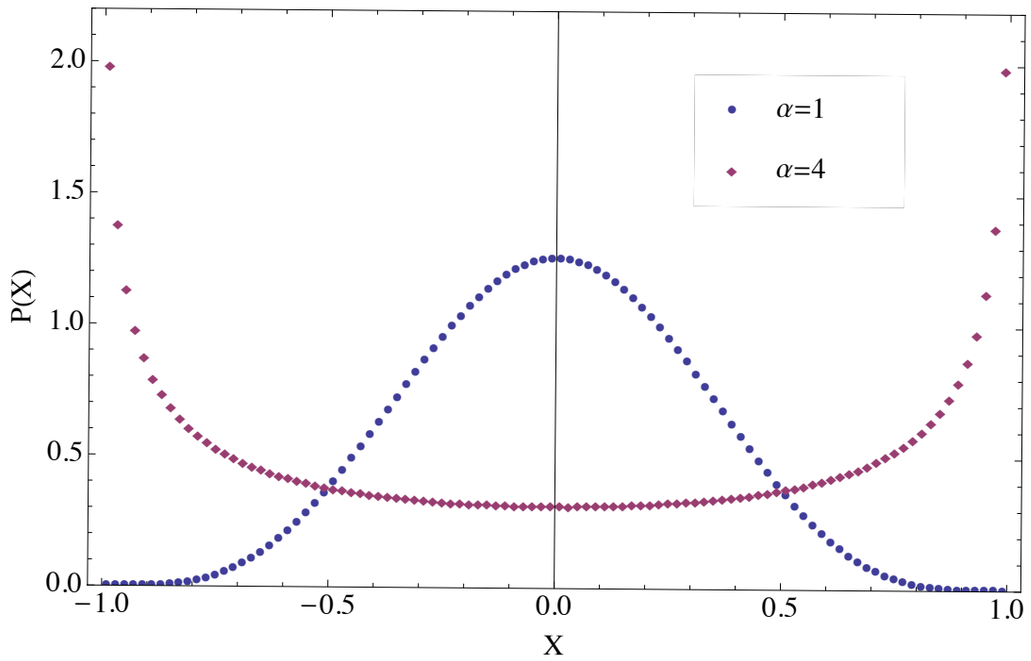
$$x = \frac{4}{\pi} \tan^{-1} \frac{\|Q_2\|}{\|Q_1\|} - 1$$



I. Horvath, N. Isgur, J. McCune, and H. B. Thacker, *Phys. Rev.* **D65** (2002) 014502

Dynamical polarization

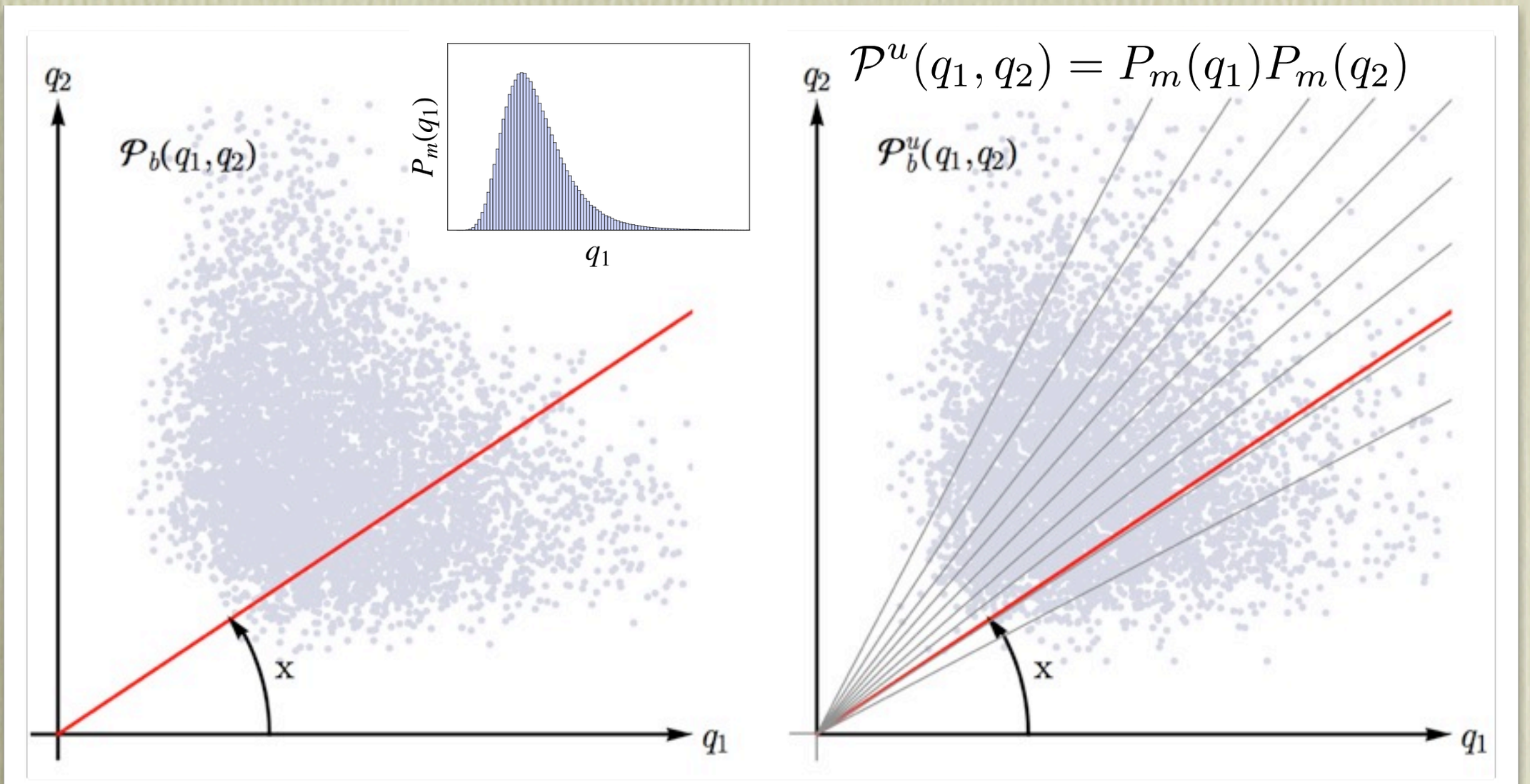




$$X = \mathrm{sgn}(x)|x|^{\alpha}$$

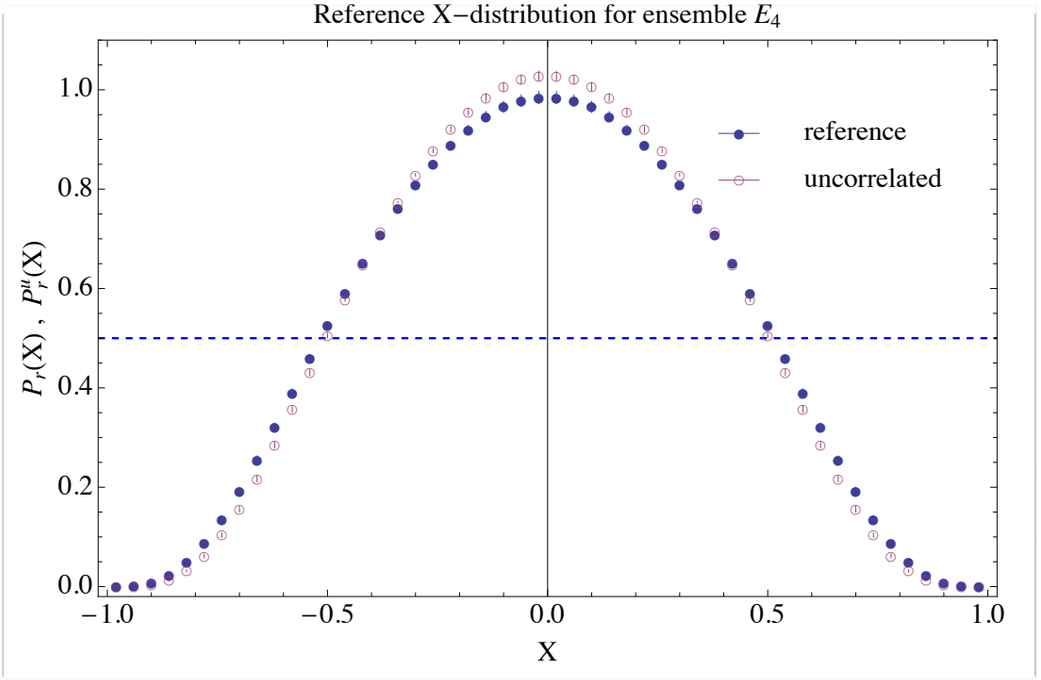
$$X = \frac{\left(\frac{\|Q_2\|}{\|Q_1\|}\right)^{\alpha} - 1}{\left(\frac{\|Q_2\|}{\|Q_1\|}\right)^{\alpha} + 1}$$

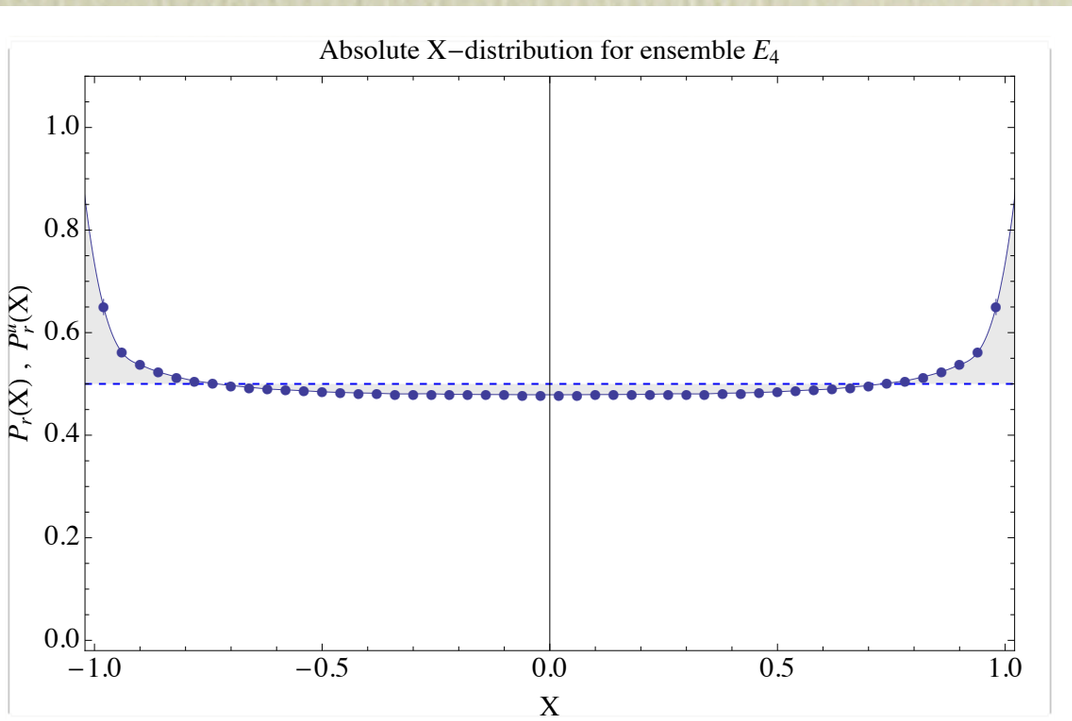
Dynamical polarization



AA, T. Draper, I. Horvath, and T. Streuer, *Annals of Physics* **326** (2011) 1941

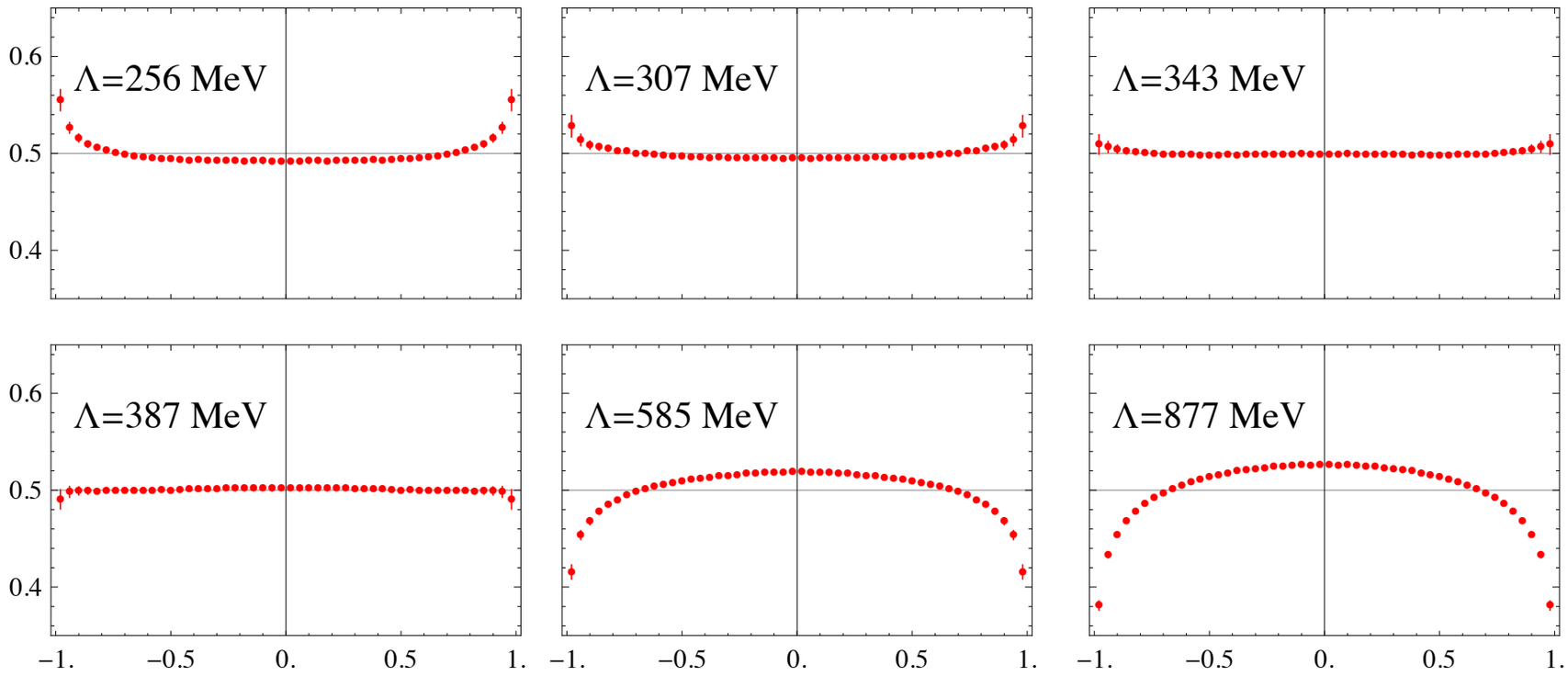
Dynamical polarization





AA, T. Draper, I. Horvath, and T. Streuer, *Annals of Physics* **326** (2011) 1941

Chiral polarization scale



$$D_{\rm ov}\psi = \lambda\psi \quad Q_1 = \frac{1}{2}(1+\gamma_5)\psi \quad Q_2 = \frac{1}{2}(1-\gamma_5)\psi$$

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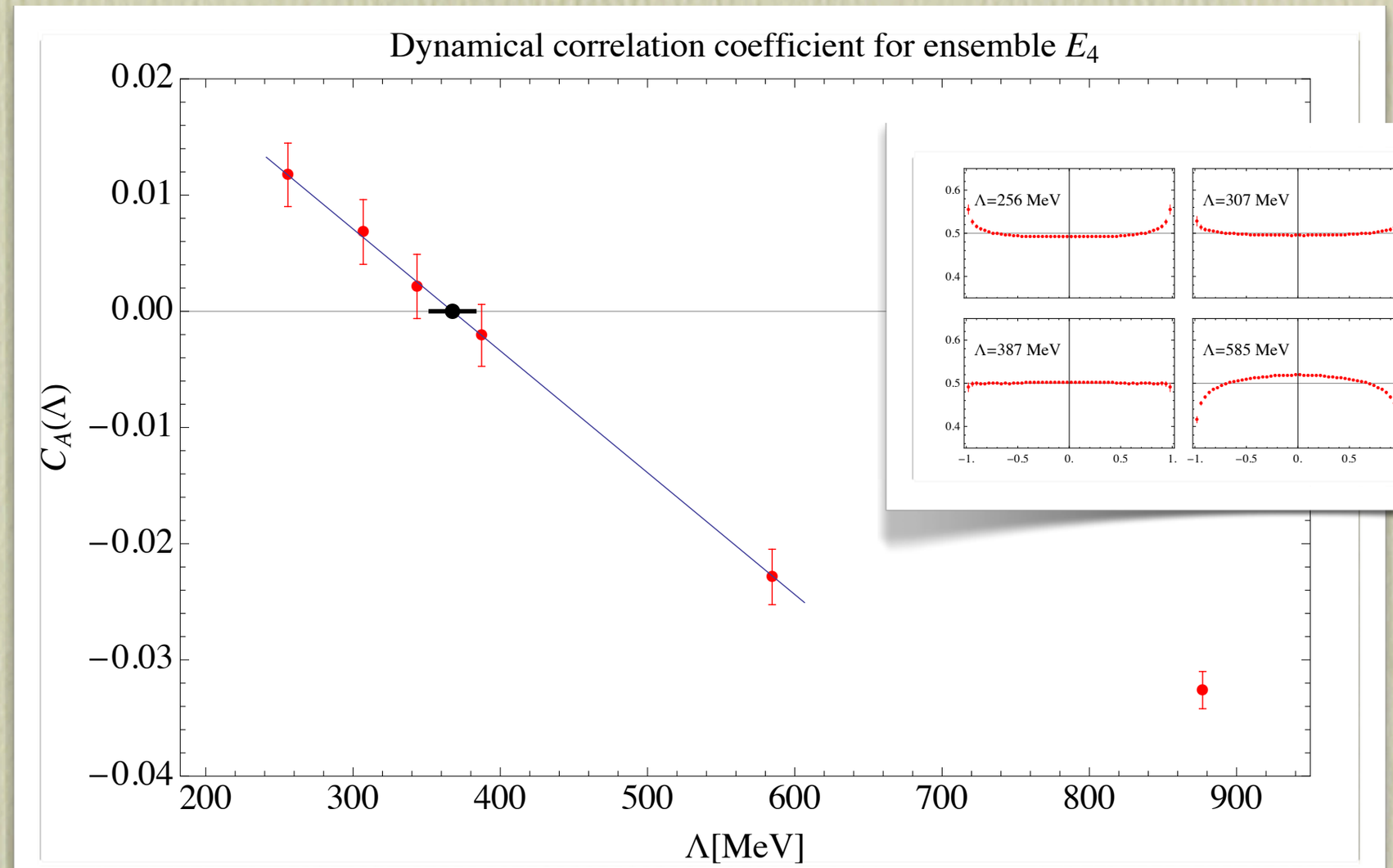
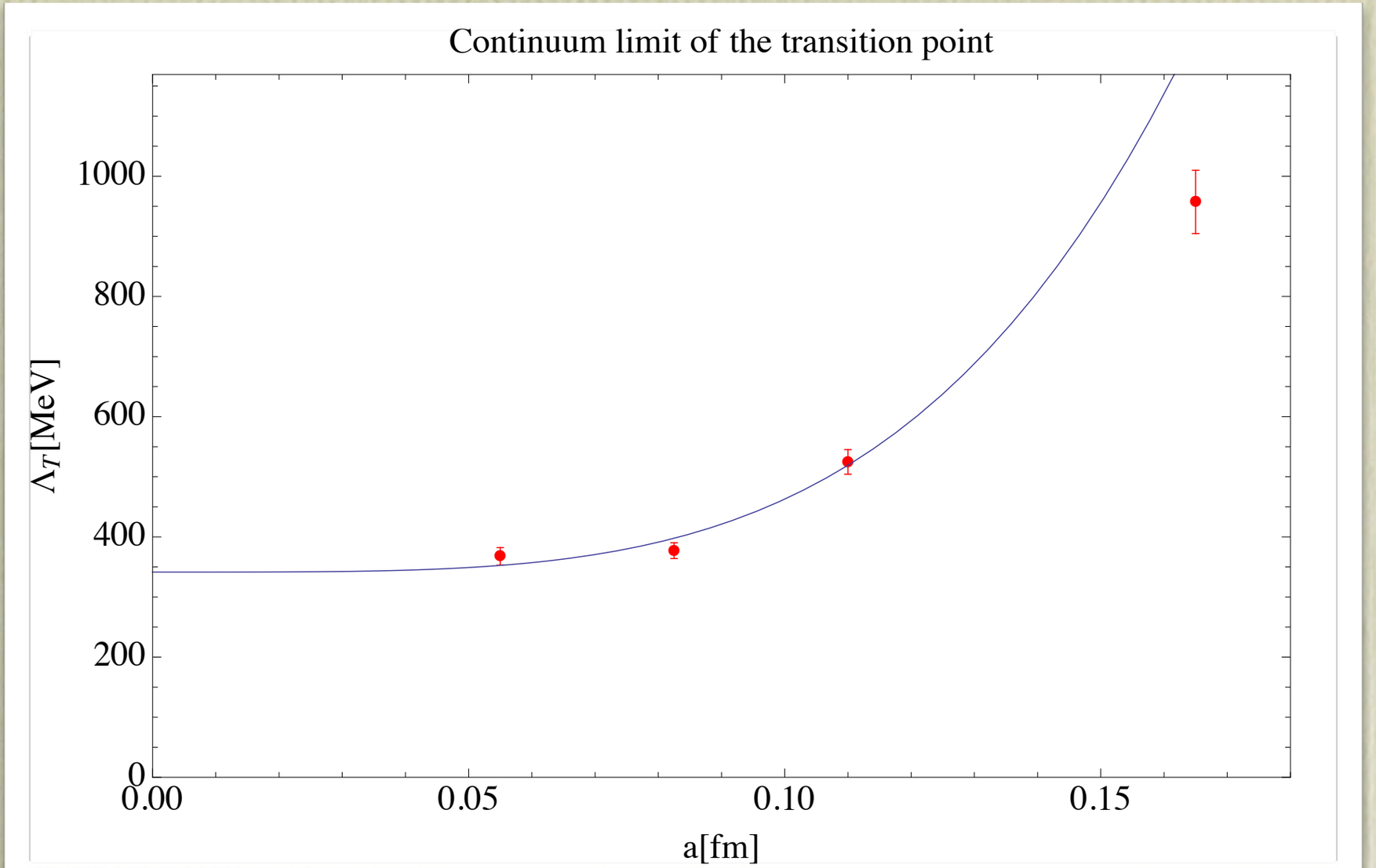
Chiral polarization scale



$$\Gamma \equiv \int_{-1}^{1} dX\, |X| P_A(X) \quad C_A = 2\Gamma - 1$$

Chiral polarization scale



AA, T. Draper, I. Horvath, and T. Streuer, *Annals of Physics* **326** (2011) 1941

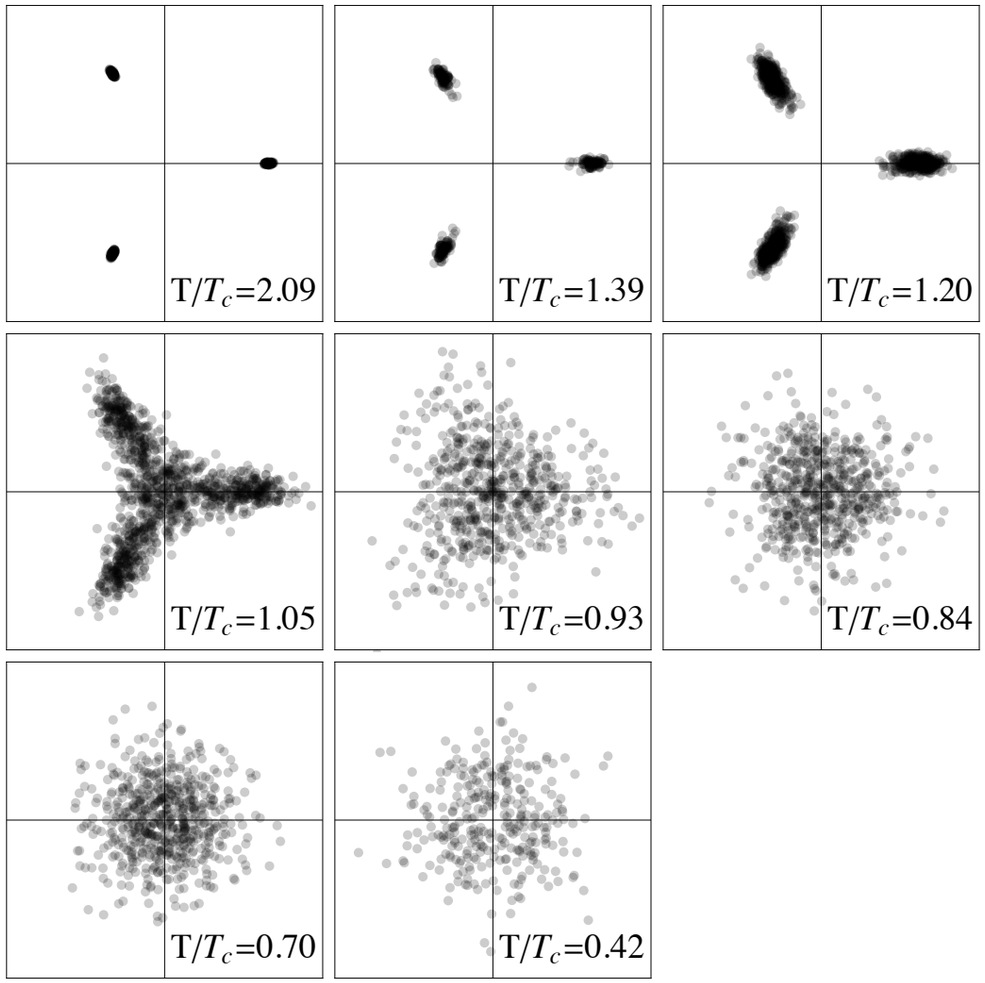
Numerical results

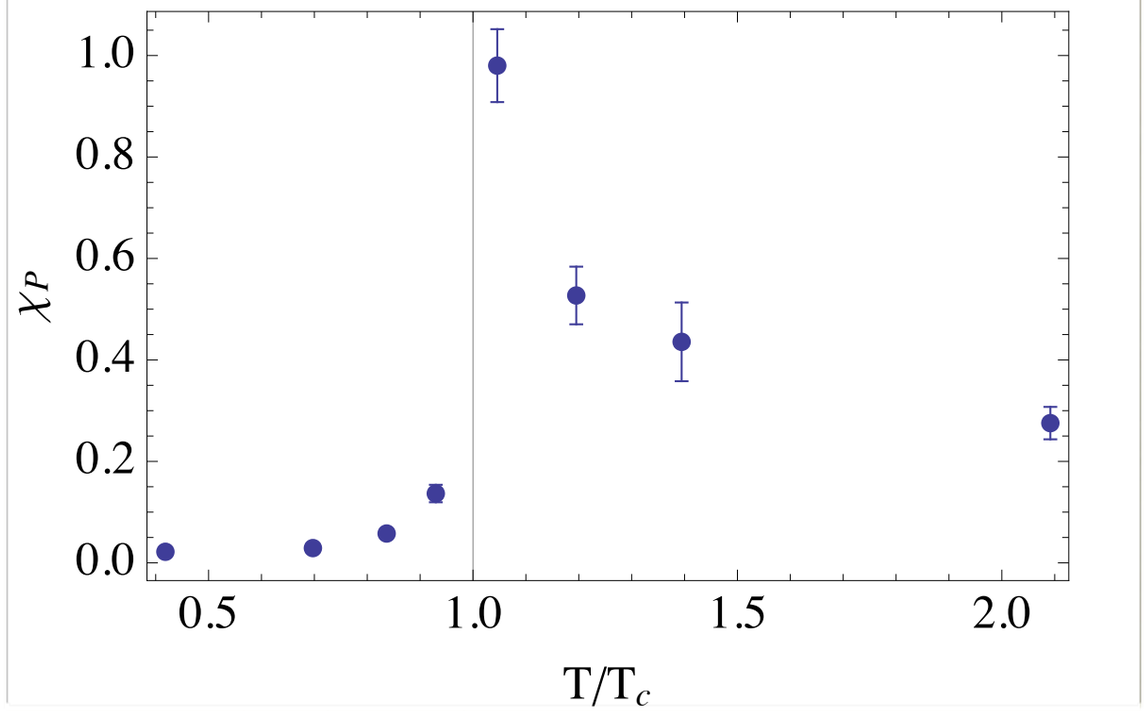
Size	Nconf	T/T_c	a[fm]
$4x20^3$	100	2.09	
$6x20^3$	100	1.39	
$7x20^3$	400	1.20	
$8x20^3$	400	1.05	0.085
$9x20^3$	200	0.93	
$10x20^3$	200	0.84	
$12x20^3$	200	0.70	
$20x20^3$	100	0.42	

Pure gauge configurations using Wilson action

ALPHA Collaboration, *Nucl. Phys.* **B535** (1998) 389–402.

Polyakov loop

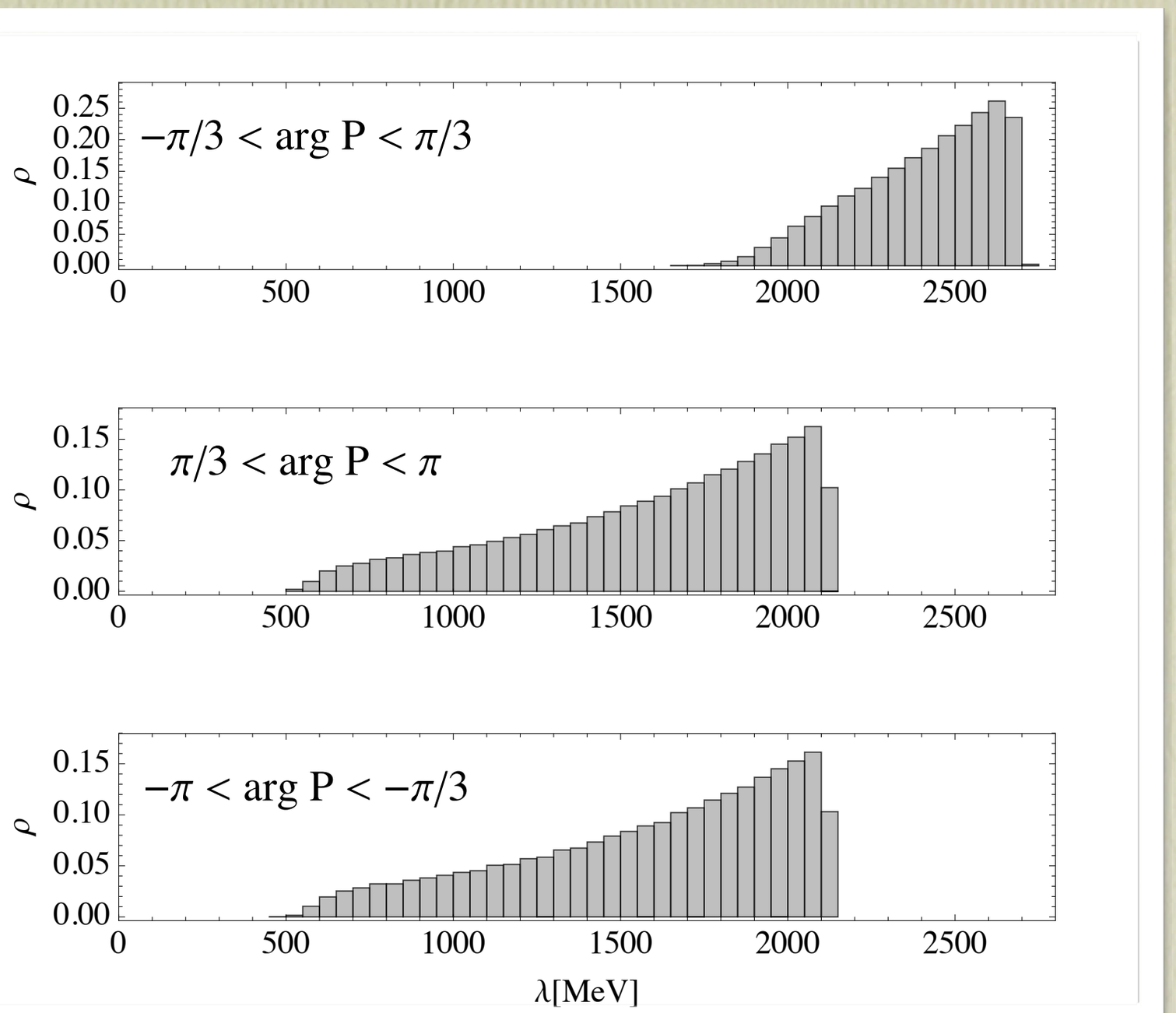




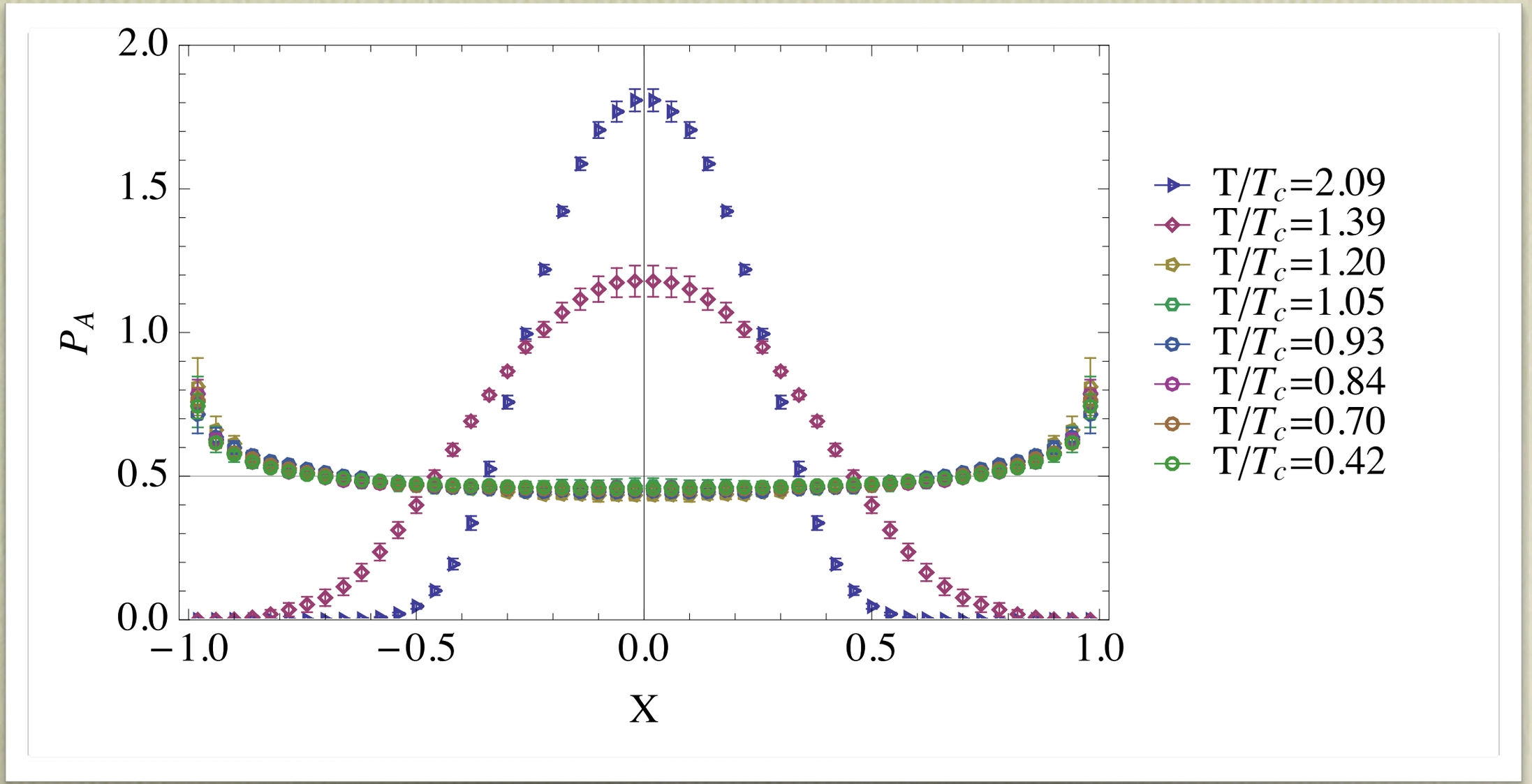
$$P = \frac{1}{3V_s} \sum_{\vec{x}} \mathrm{Tr} \left(\prod_{t=0}^{N_t-1} U_4(\vec{x}, t) \right)$$

$$\chi_P = V_s \left(\langle |P|^2 \rangle - \langle |P| \rangle^2 \right)$$

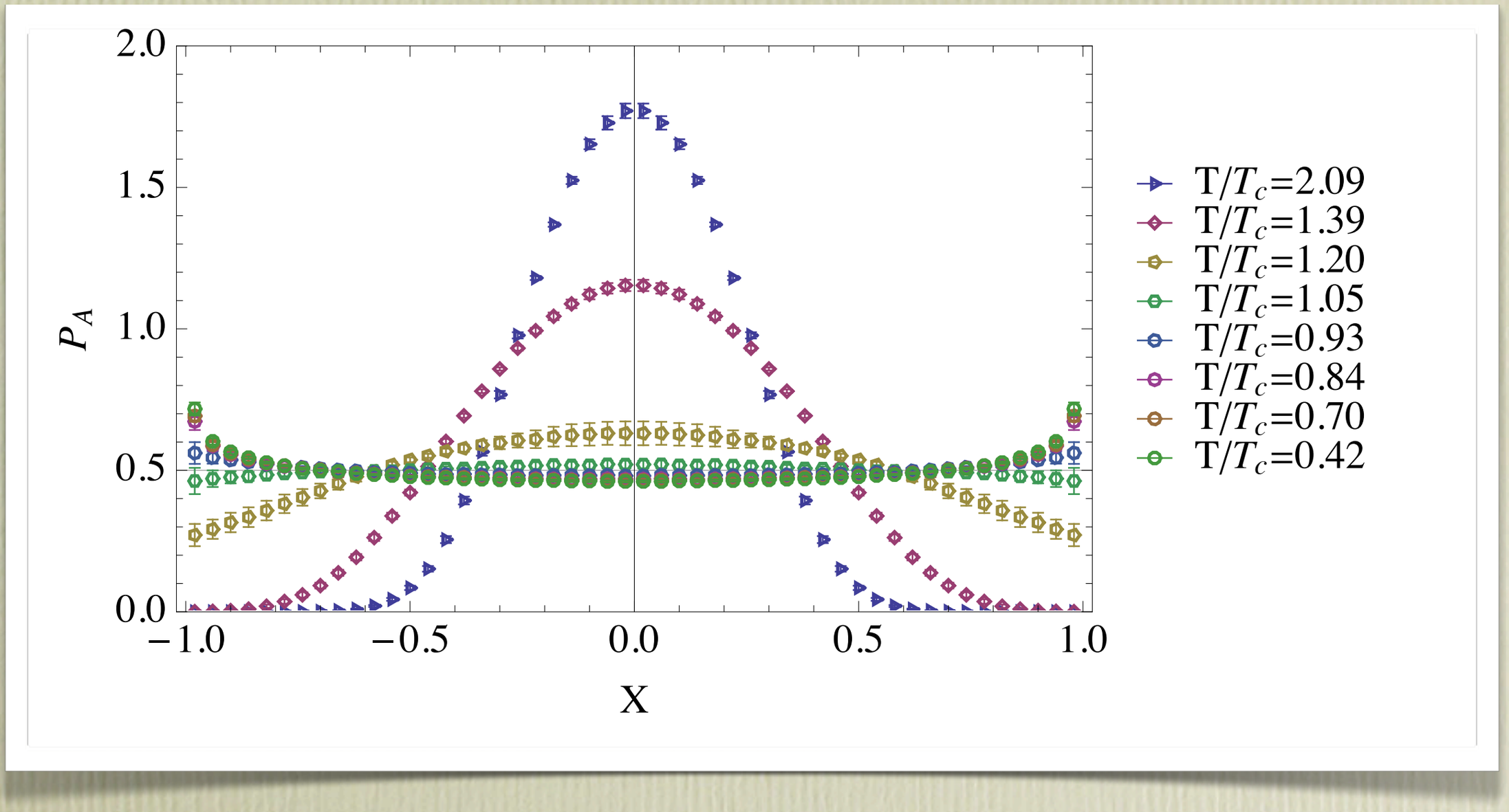
Real sector


$-\pi/3 < \arg P < \pi/3$
$\pi/3 < \arg P < \pi$
$-\pi < \arg P < -\pi/3$
ρ
0.25
0.20
0.15
0.10
0.05
0.00
0
500
1000
1500
2000
2500
λ[MeV]

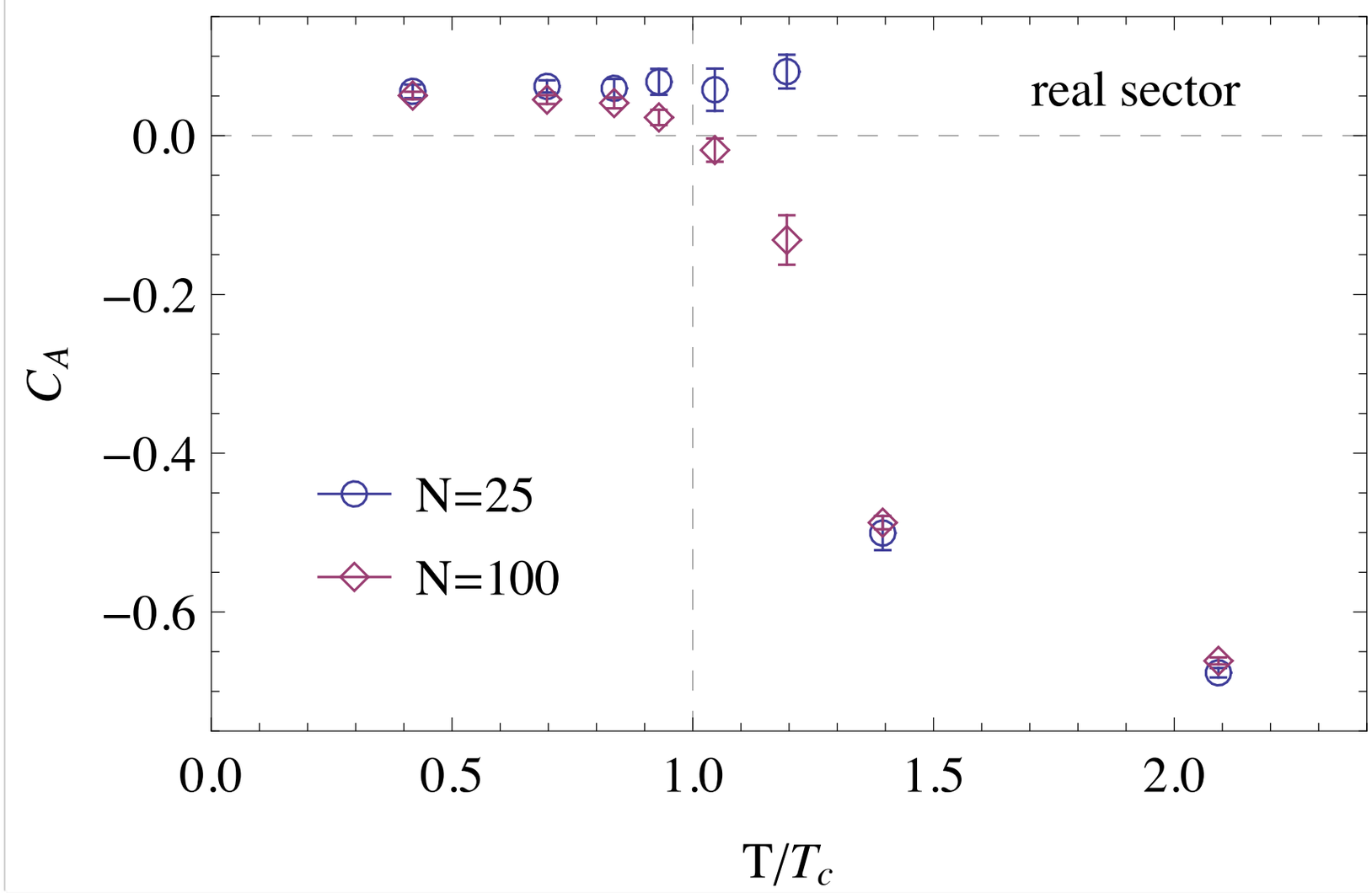
Low modes chiral polarization



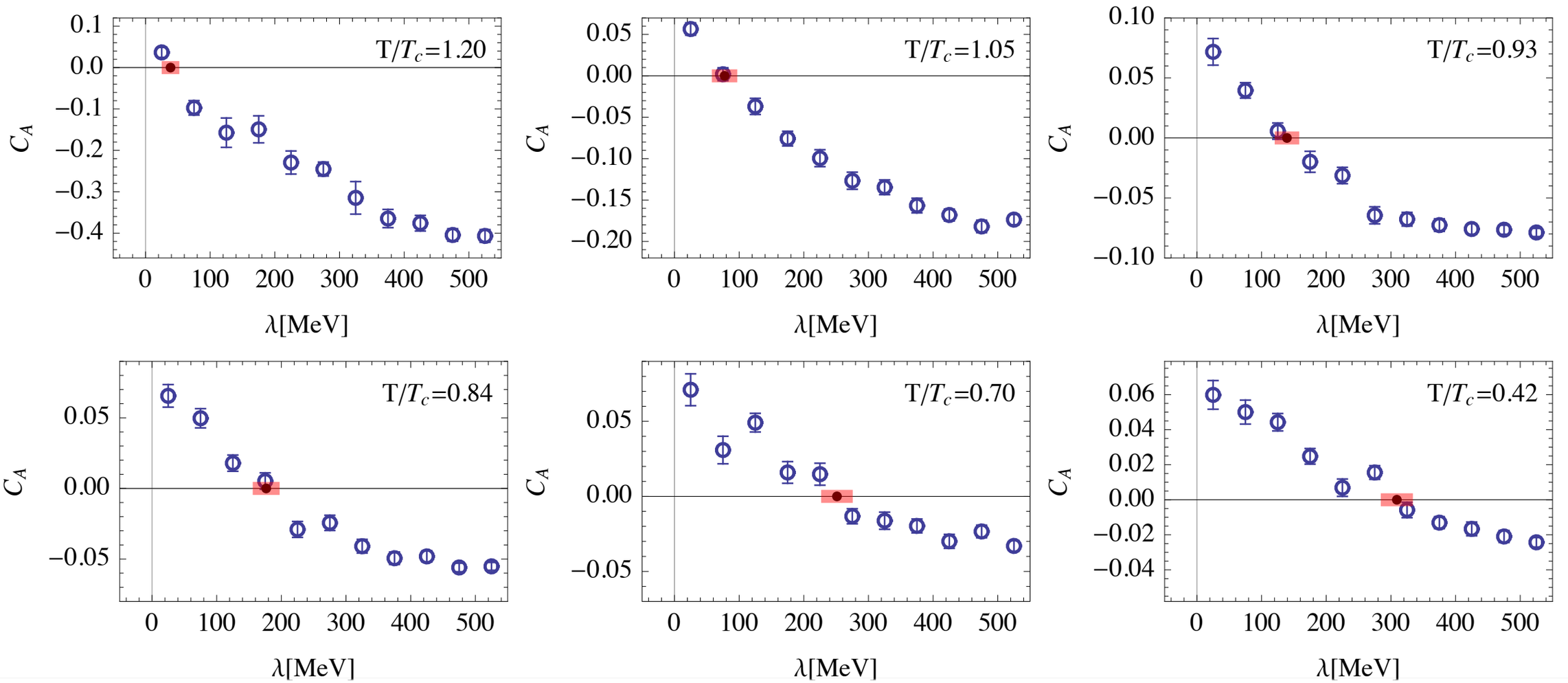
Low modes chiral polarization



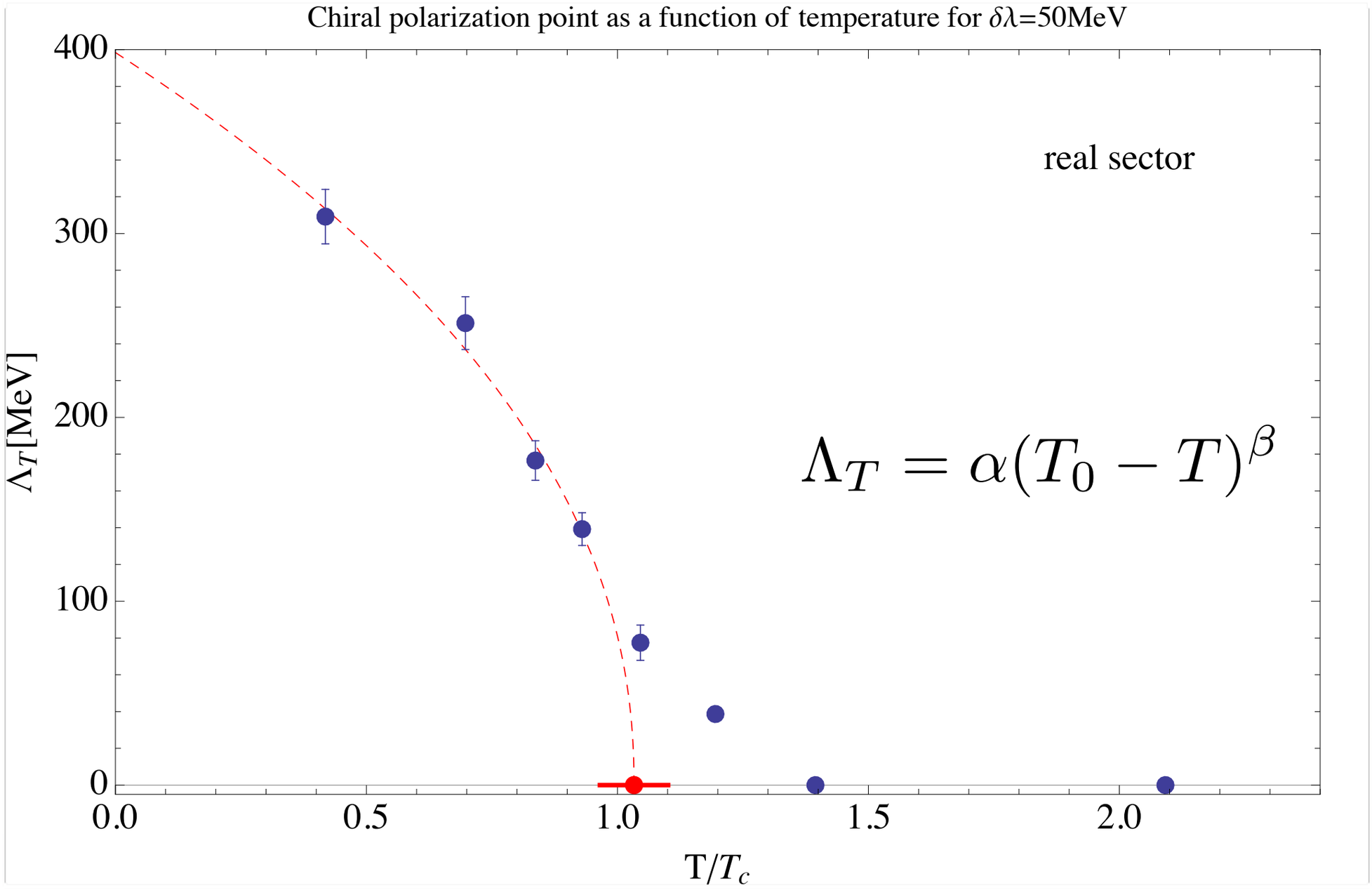
Low modes chiral polarization



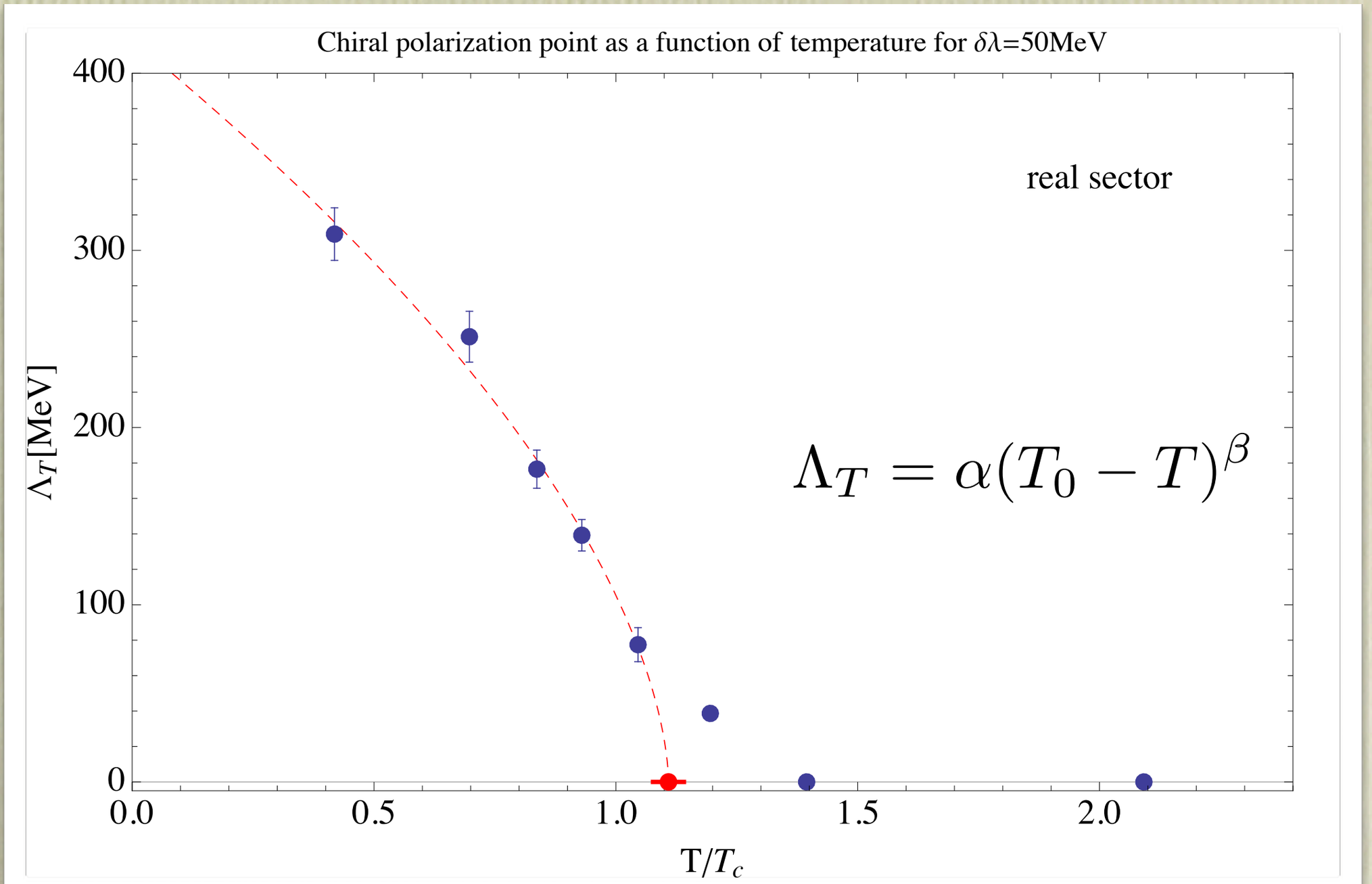
Eigenvalue dependence



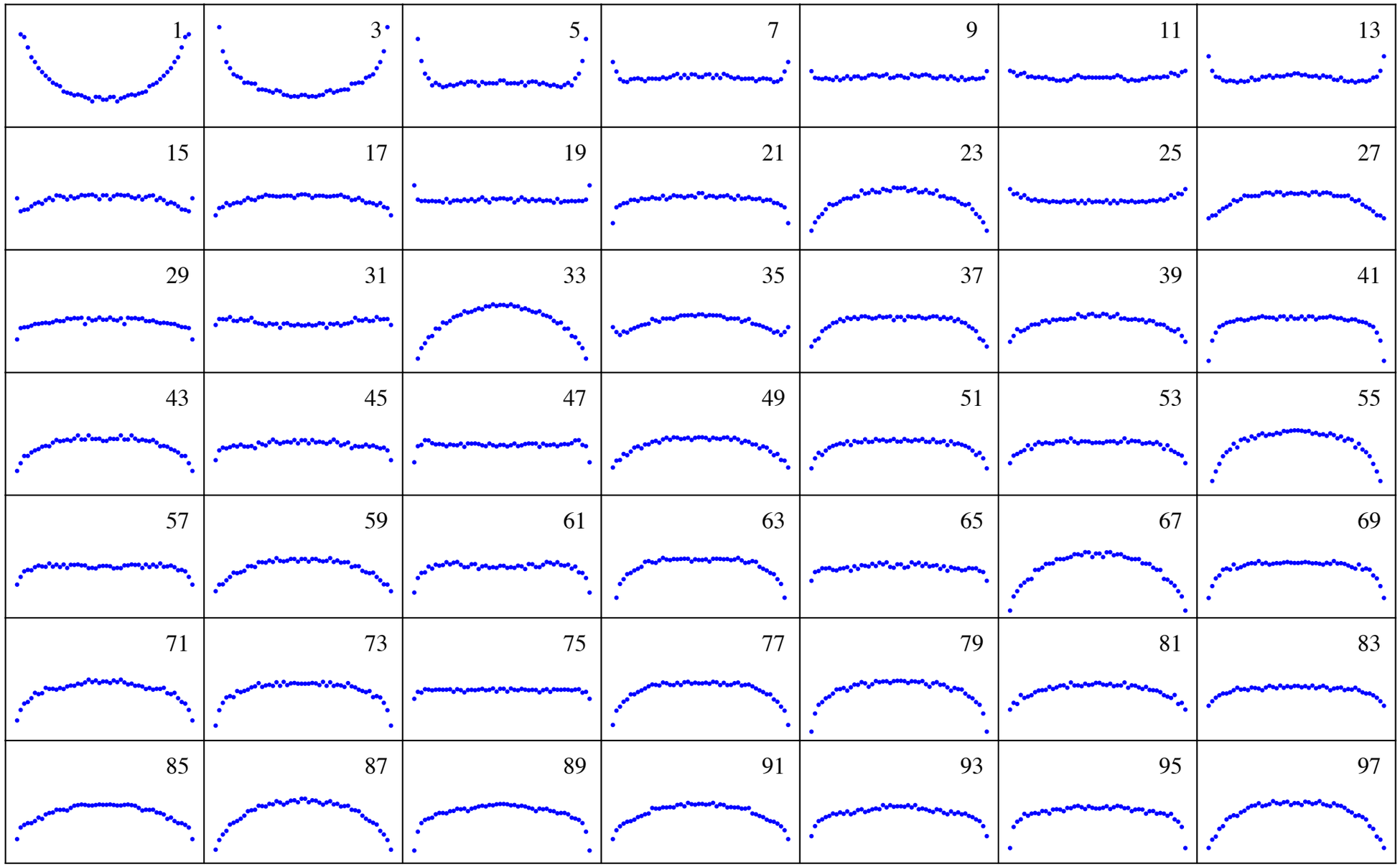
Chiral polarization scale



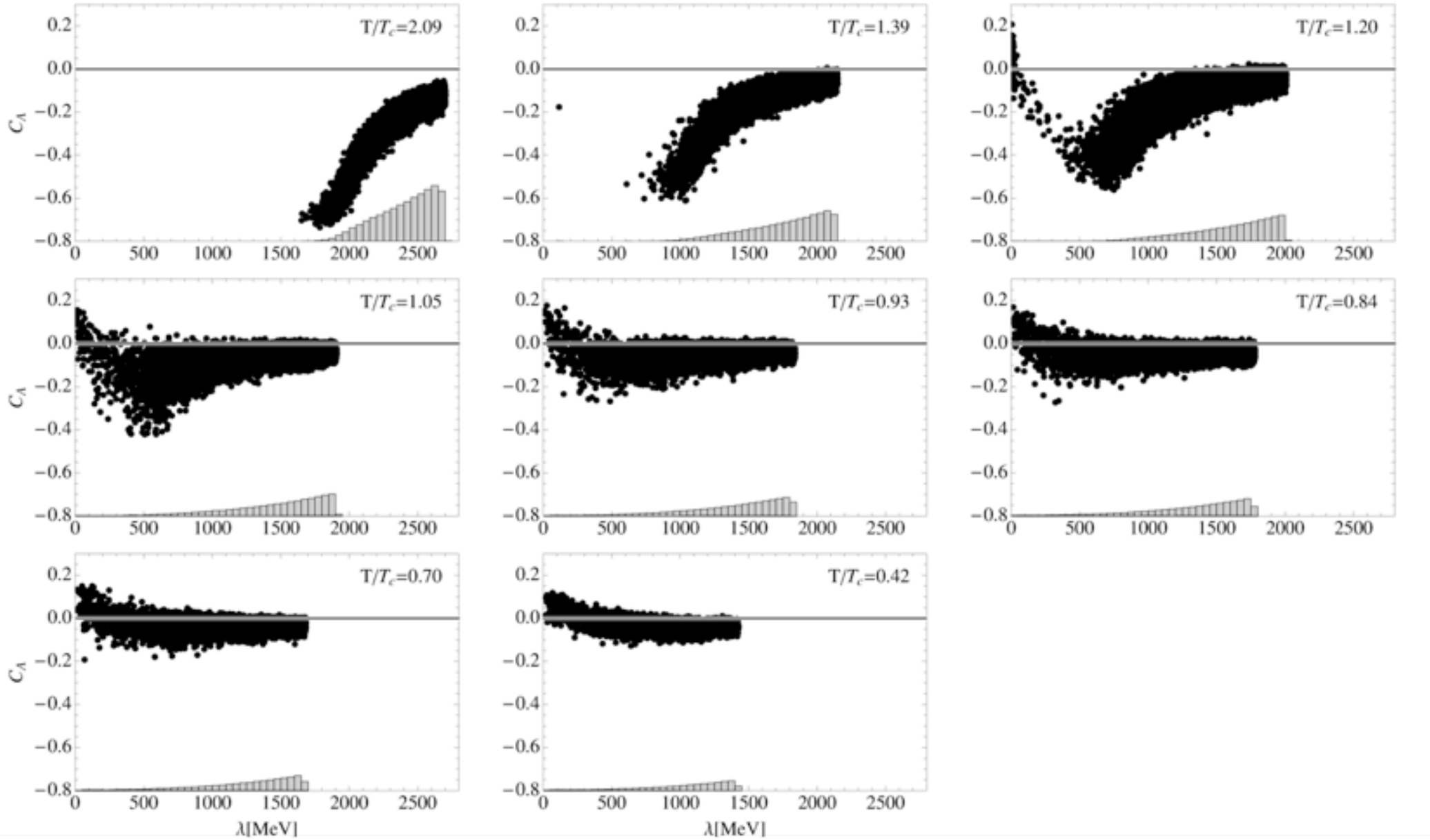
Chiral polarization scale



Individual mode polarization



Correlation coefficient



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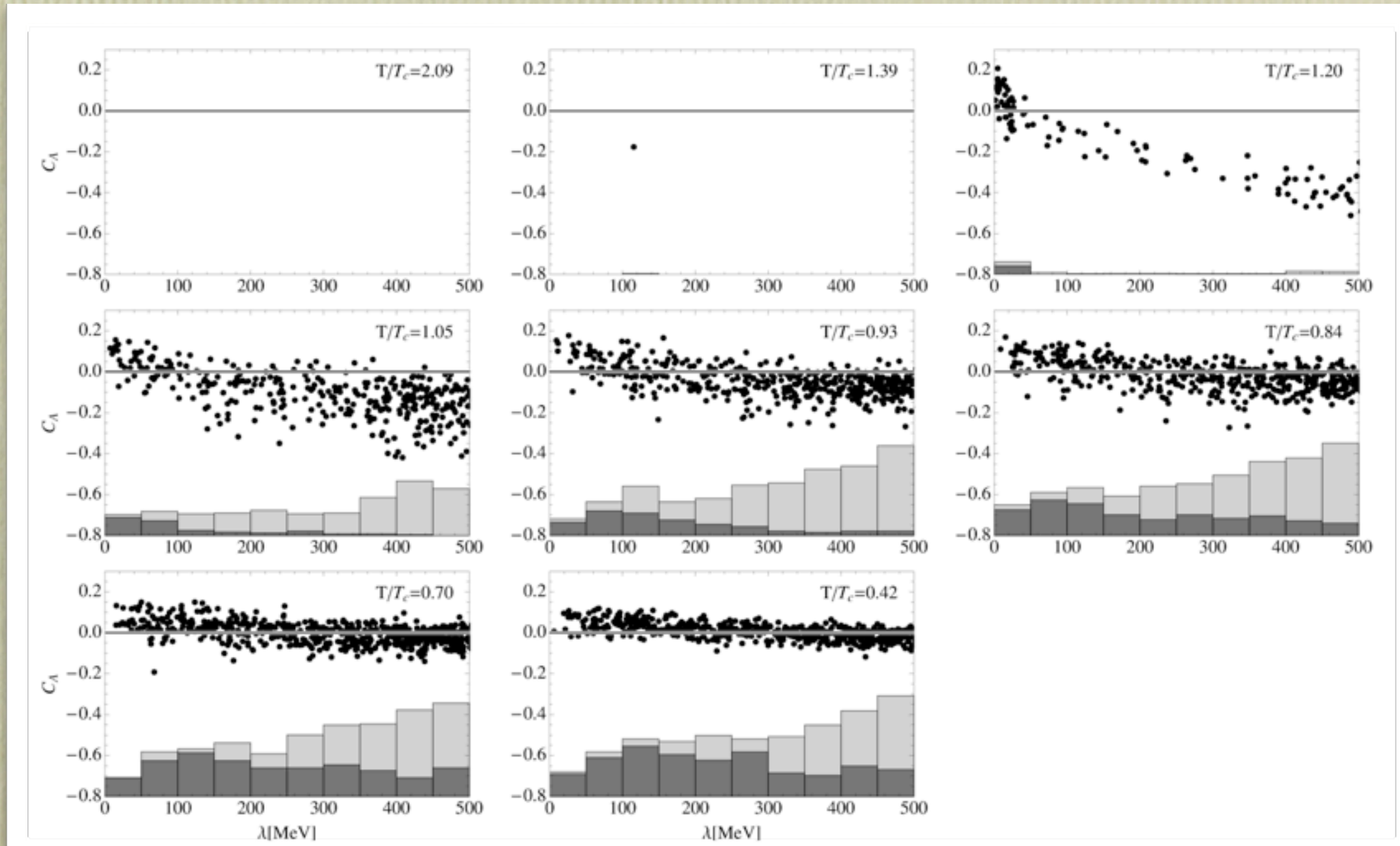


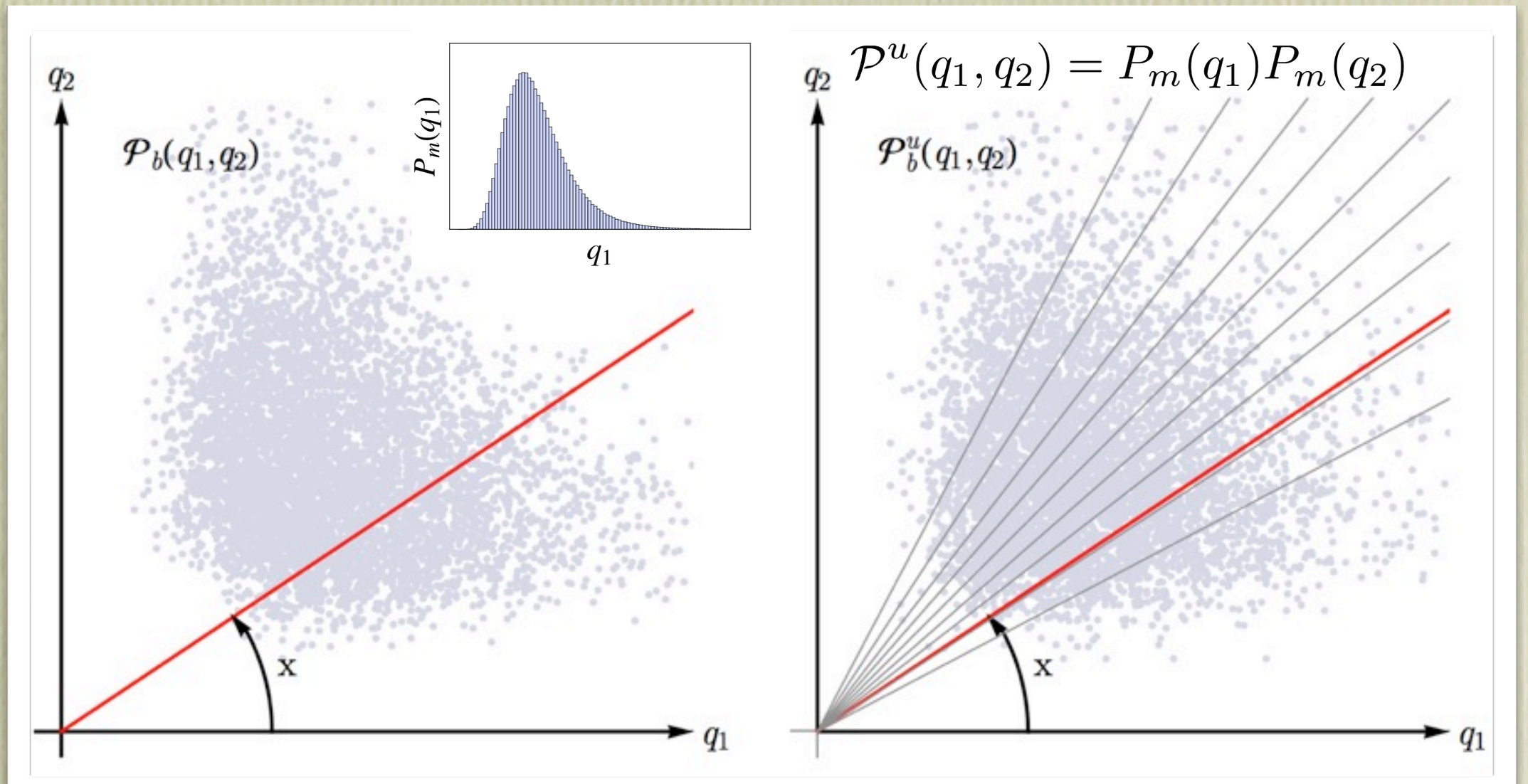
R. G. Edwards, U. M. Heller, J. E. Kiskis, and R. Narayanan, *Phys.Rev.* **D61** (2000) 074504.

Conclusions and outlook

- We computed the polarization scale for SU(3) pure gauge configurations as a function of temperature
- We find that the polarization scale decreases as we approach the phase transition and vanishes above the phase transition
- The near zero modes, connected to chiral symmetry breaking, are mostly (possibly all) polarized
- Extrapolations from below the phase transition are consistent with a picture where the polarization scale vanishes at T_c
- However, the presence of a small density of near-zero modes at temperatures as high as 1.20 T_c modifies this picture
- These are polarized modes and it is not yet clear whether they are a quenching artifact, a finite volume effect or really dynamical

Backup slides

Dynamical polarization



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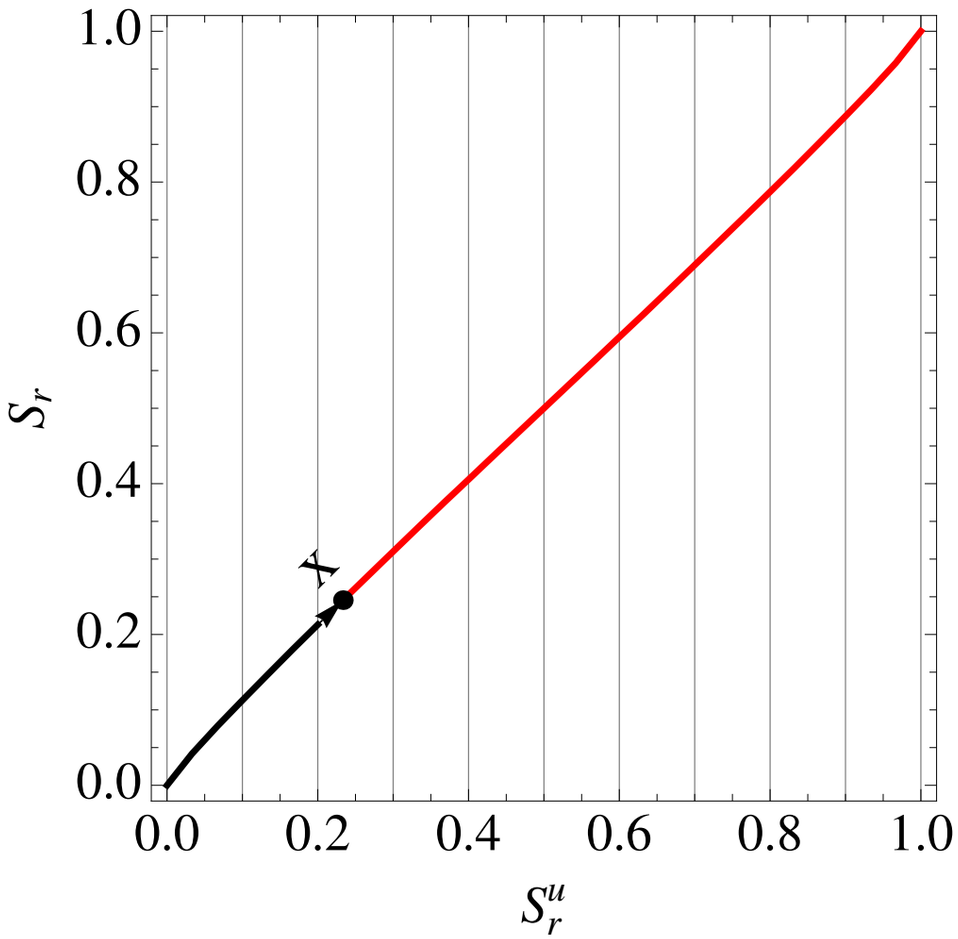

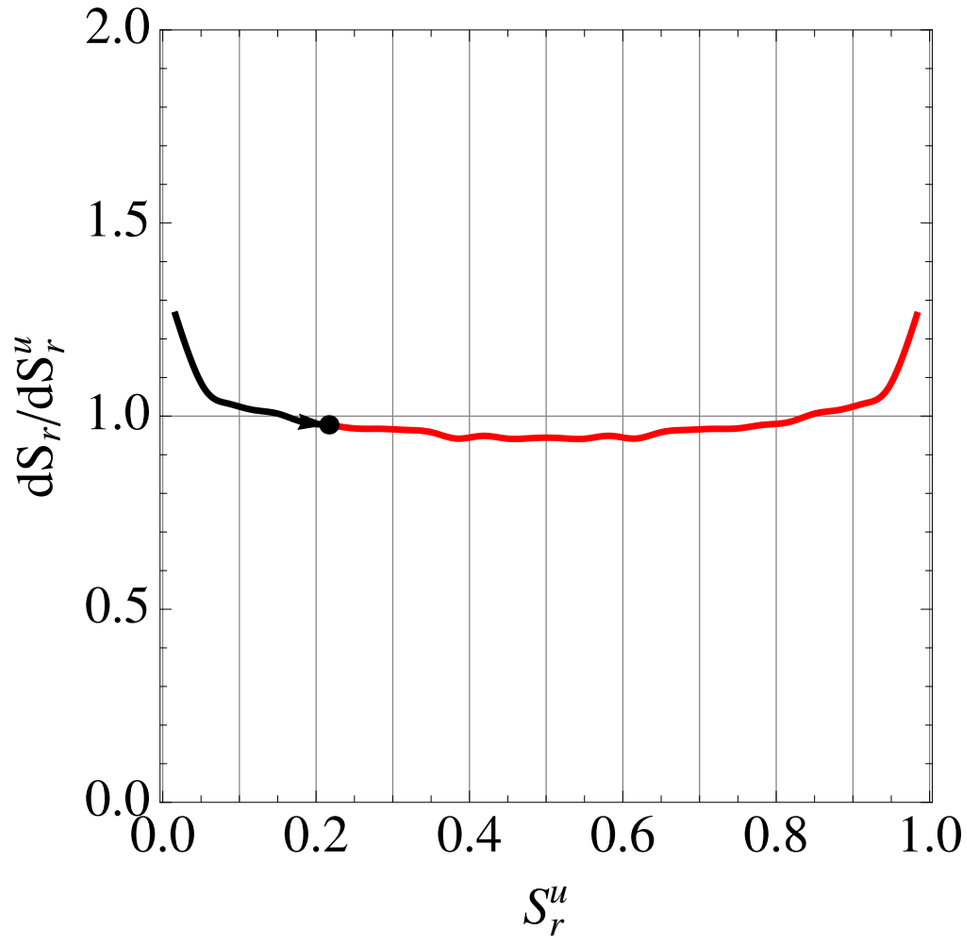

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