Hot SU(2) Glue around Deconfinement

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Helpful Glue!!

Gluon and Confinement

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Gluon propagator in Landau gauge

$$
\begin{aligned}
D^{ab}_{\mu\nu}(p) &= \sum_x e^{-2i\pi k\cdot x} \langle A^a_\mu(x)\, A^b_\nu(0)\rangle \\
&= \delta^{ab} \left(g_{\mu\nu} - \frac{p_\mu\, p_\nu}{p^2} \right) D(p^2)
\end{aligned}
$$

Early simulations: Mandula & Ogilvie, PLB 1987

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Dimensional-reduction picture (based ont the 3D-adjoint-Higgs model) suggests a confined magnetic gluon, associated to a nontrivial magnetic mass

Previous Lattice Studies

Above predictions confirmed at high T:

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Note: “masses” from $D_L(0)^{-1/2}$

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Note: $D(0)^{-1/2} \; = \; \sqrt{(a^2 + b^2)/C}$ mixes m_R and m_I and depends on the normalization C

Gribov-Stingl Form for IR Gluon

Gribov-type propagator has purely-imaginary complex-conjugate poles

$$D(p^2) \;=\; C\,\frac{p^2}{p^4\;+\;b^2}$$

(vanishes at $p = 0$, expected in Gribov-Zwanziger scenario)

Gribov-Stingl form (1986) allows for complex conjugate poles

$$D(p^2) \;=\; C\,\frac{p^2\;+\;d}{(p^2+a)^2\;+\;b^2} \;=\; C\,\frac{p^2\;+\;d}{p^4\;+\;u^2\,p^2\;+\;t^2}$$

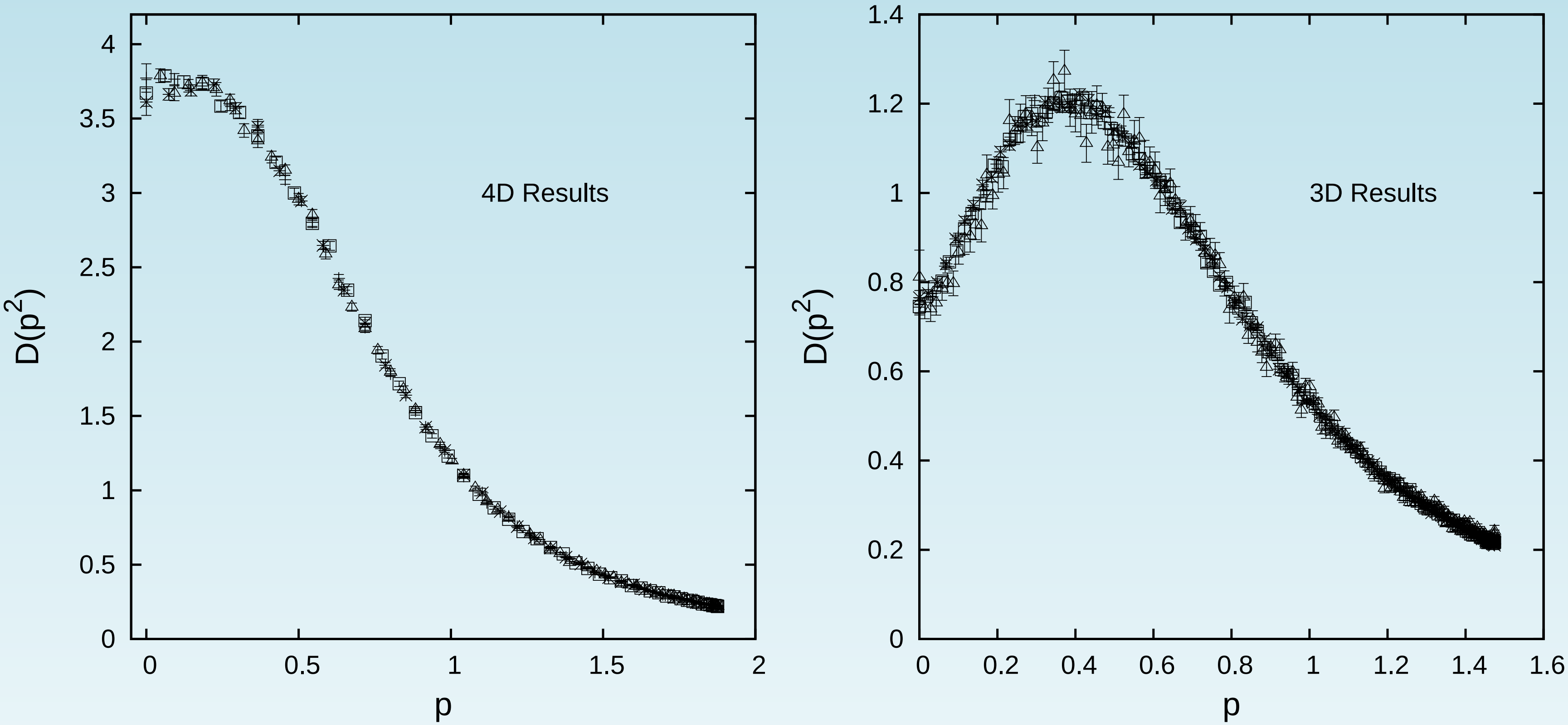
Poles at masses $m^2 \;=\; a \pm ib \;\Rightarrow\; m \;=\; m_R + im_I$

In general: pairs of (complex-conjugate) poles $+$ real poles, starting from p^6 in the denominator, p^4 in numerator

More recently: massive propagator as a consequence of condensates, in Refined Gribov-Zwanziger scenario (Dudal et al., 2008)

Gluon Propagator at $T = 0$

Cucchieri, T.M. PRL 2008

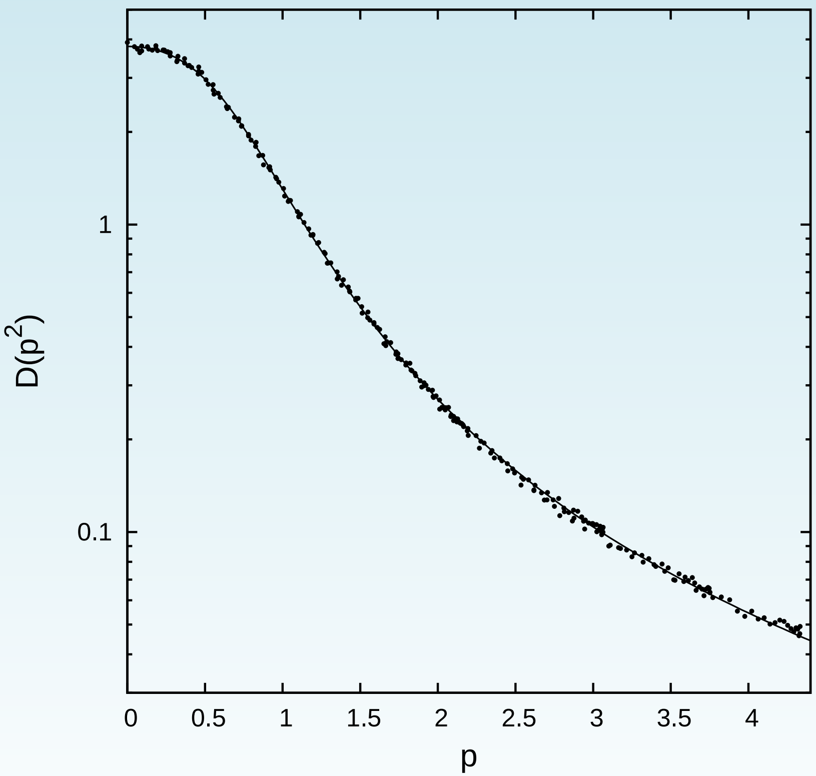


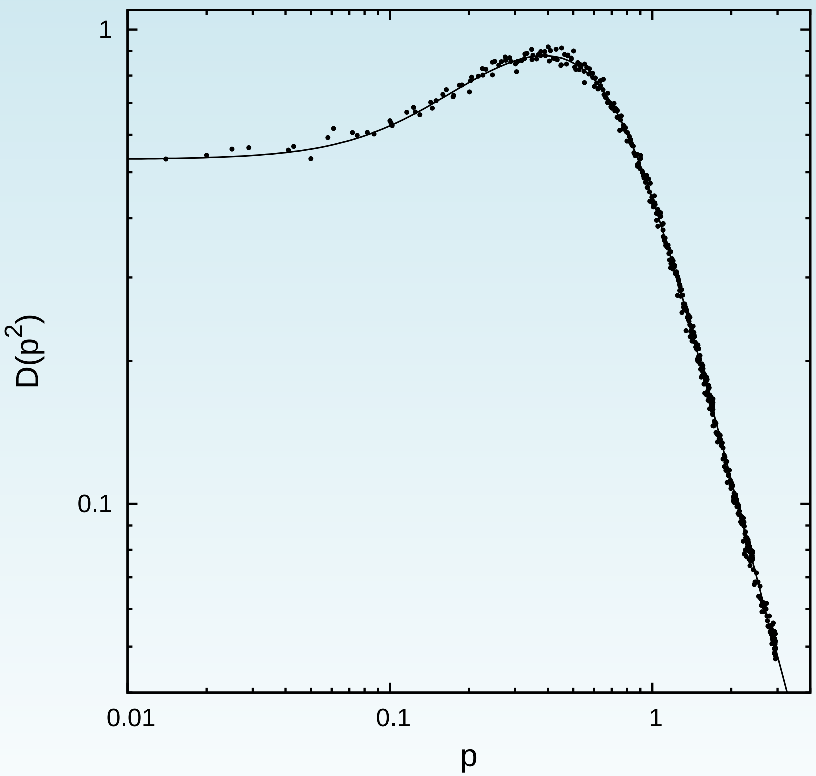
Gluon propagator $D(k)$ as a function of the lattice momenta k (both in physical units) for the pure-$SU(2)$ case in $d = 4$ (left), considering volumes of up to 128^4 (lattice extent ~ 27 fm) and $d = 3$ (right), considering volumes of up to 320^3 (lattice extent ~ 85 fm).

Gluon Fits

Fit of gluon propagator data (from A. Cucchieri & T.M., 2007) to rational forms above in $d = 4$ (left) and $d = 3$ (right) cases

Cucchieri, Dudal, T.M., Vandersickel PRD 2012



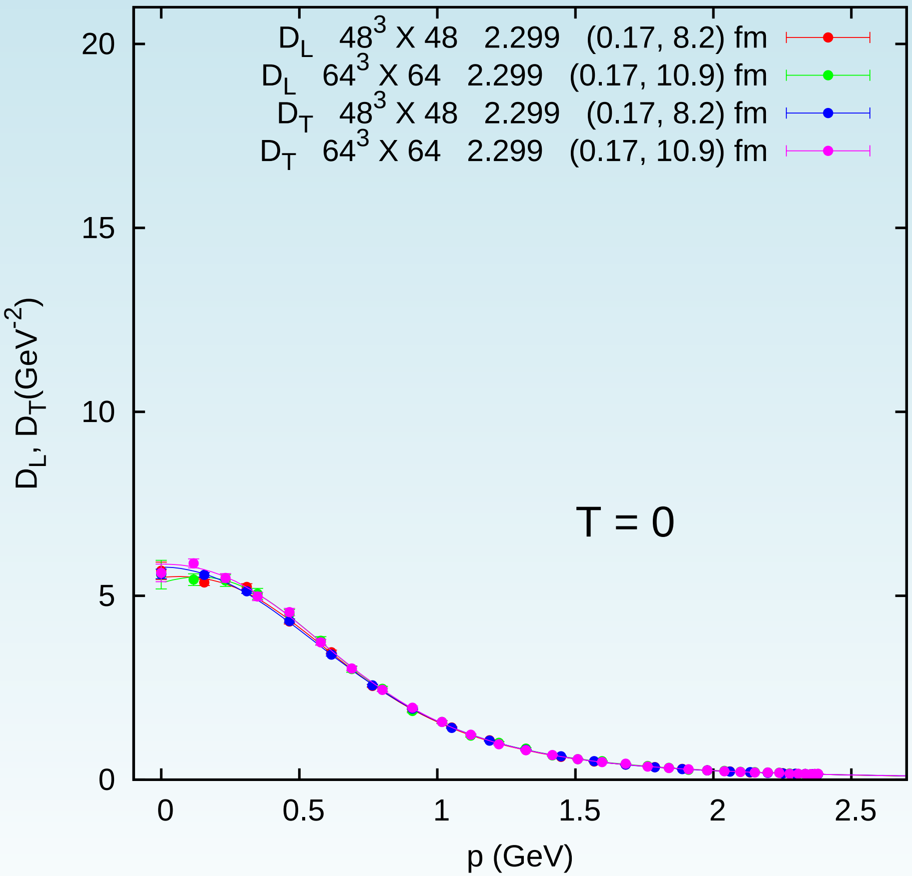


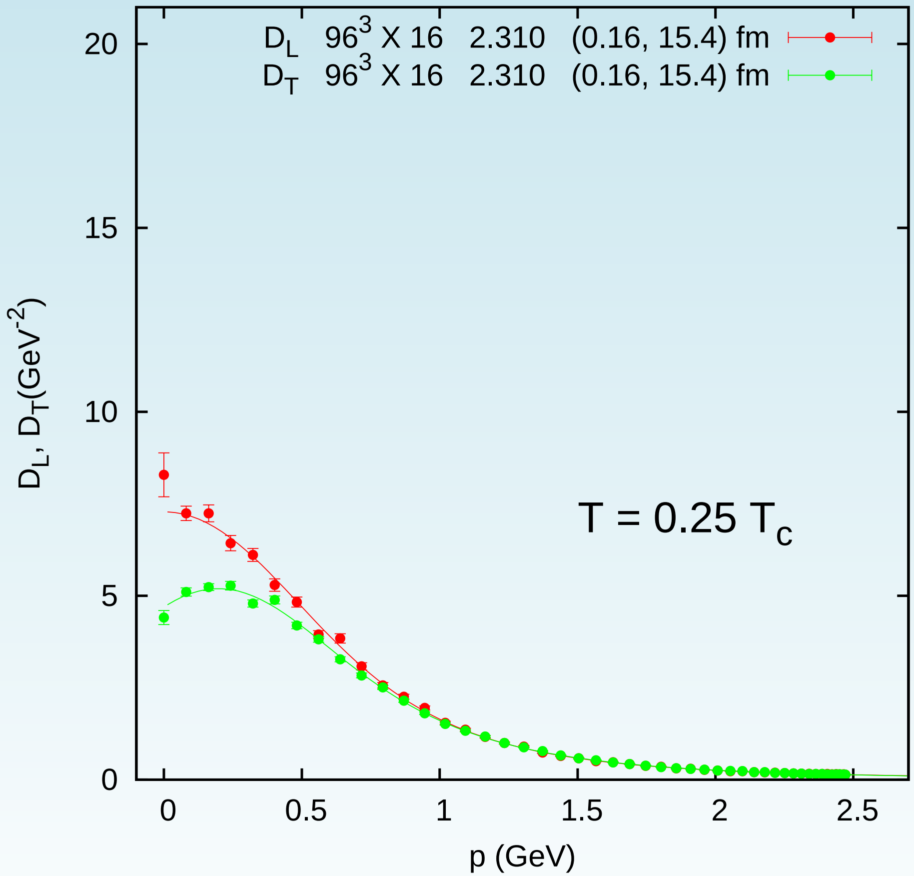
This Work (Finite T): Parameters

- pure SU(2) case, with a standard Wilson action
- cold start, projection on positive Polyakov loop configurations
- Landau-gauge fixing using stochastic overrelaxation
- lattice sizes ranging from $48^3 \times 4$ to $192^3 \times 16$
- several β values, allowing several values of the temperature $T = 1/N_t\, a$ around T_c
- gluon dressing functions normalized to 1 at 2 GeV
- masses extracted from Gribov-Stingl behavior (fits shown in plots below)

Results: Low Temperatures

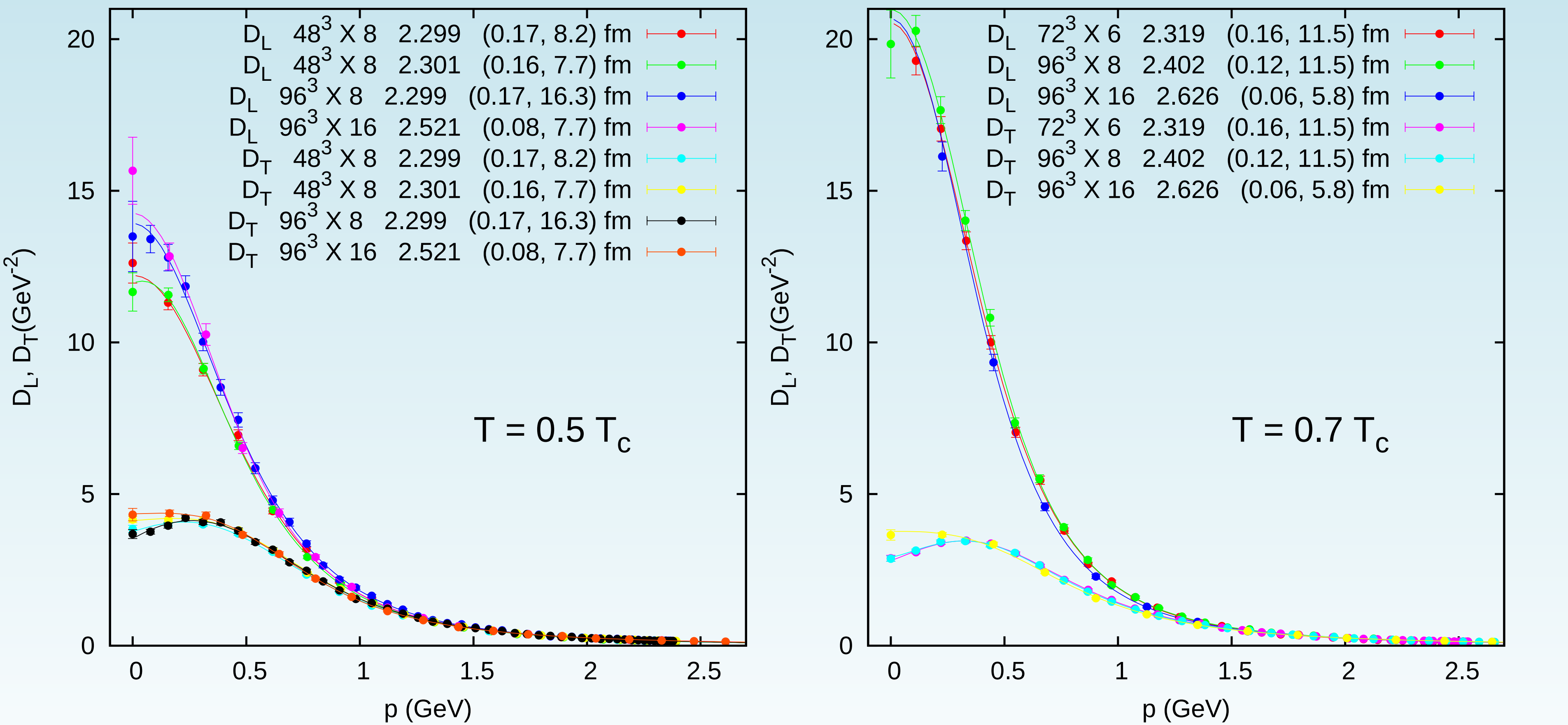
As T is turned on, magnetic propagator gets more strongly suppressed (3d-like), electric one increases



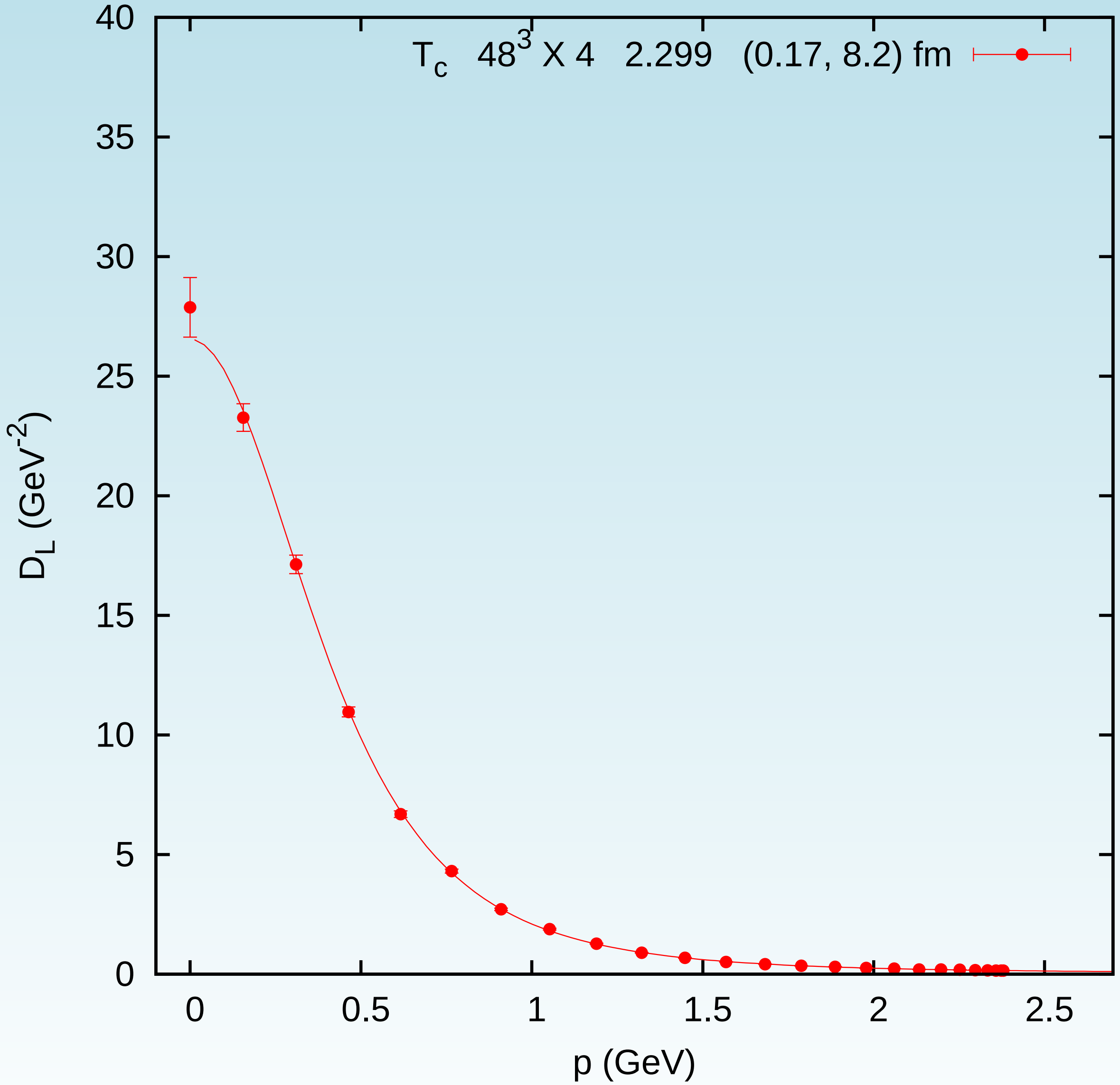


Results: Low Temperatures

At larger T, magnetic propagator slightly more suppressed, electric one increases (showing IR plateau?)



Results: Longitudinal Gluon at T_c



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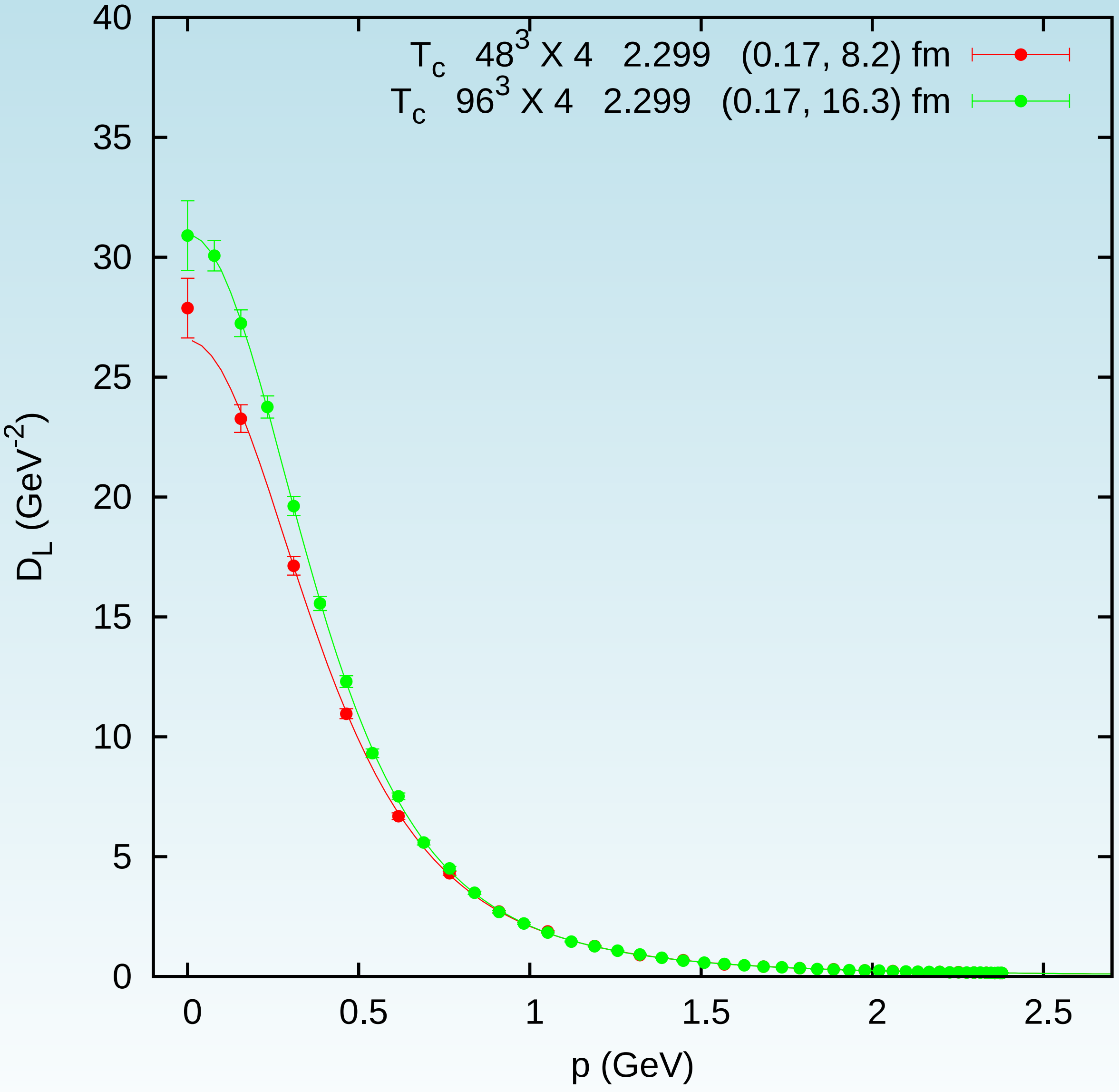

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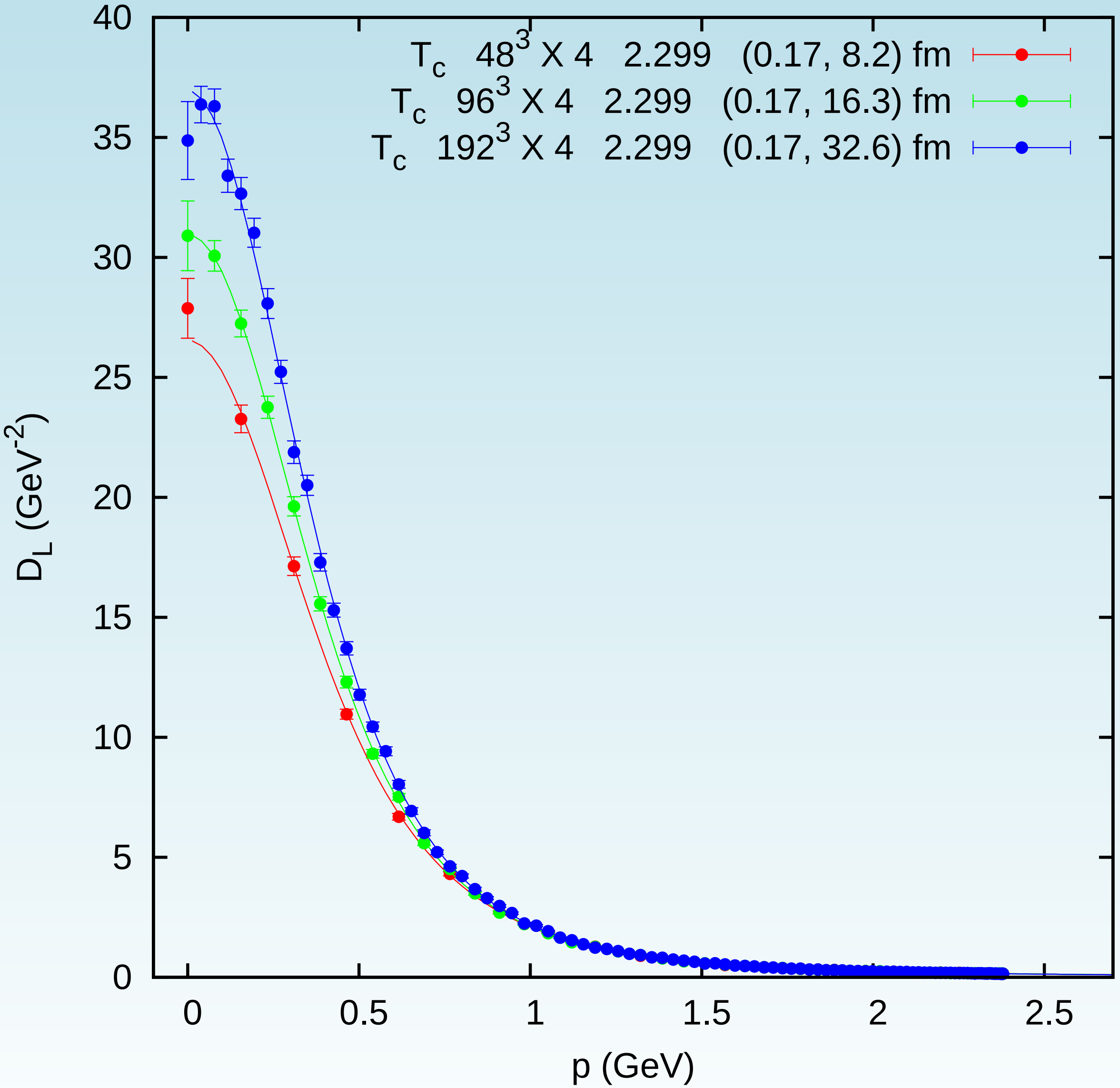

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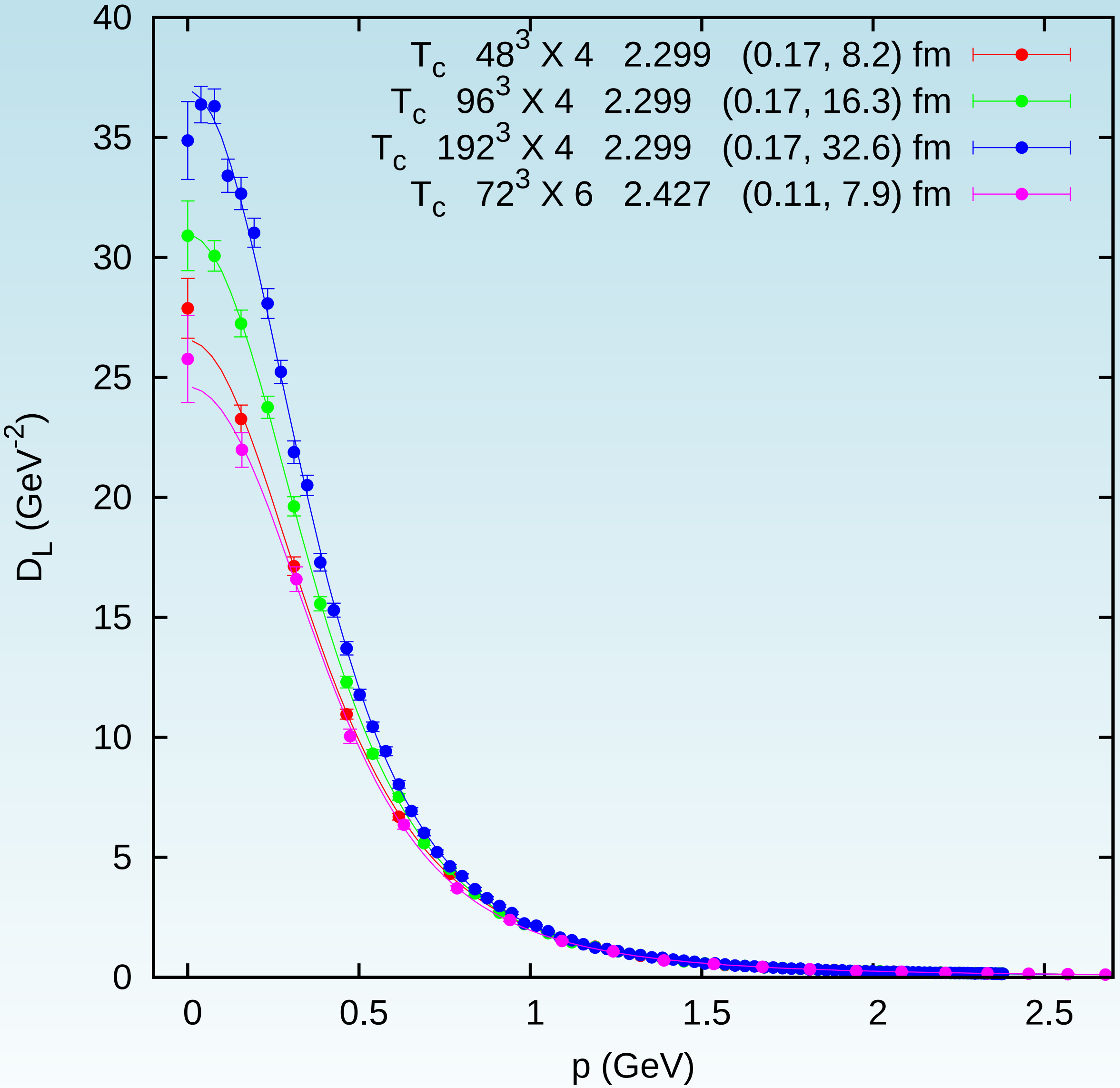

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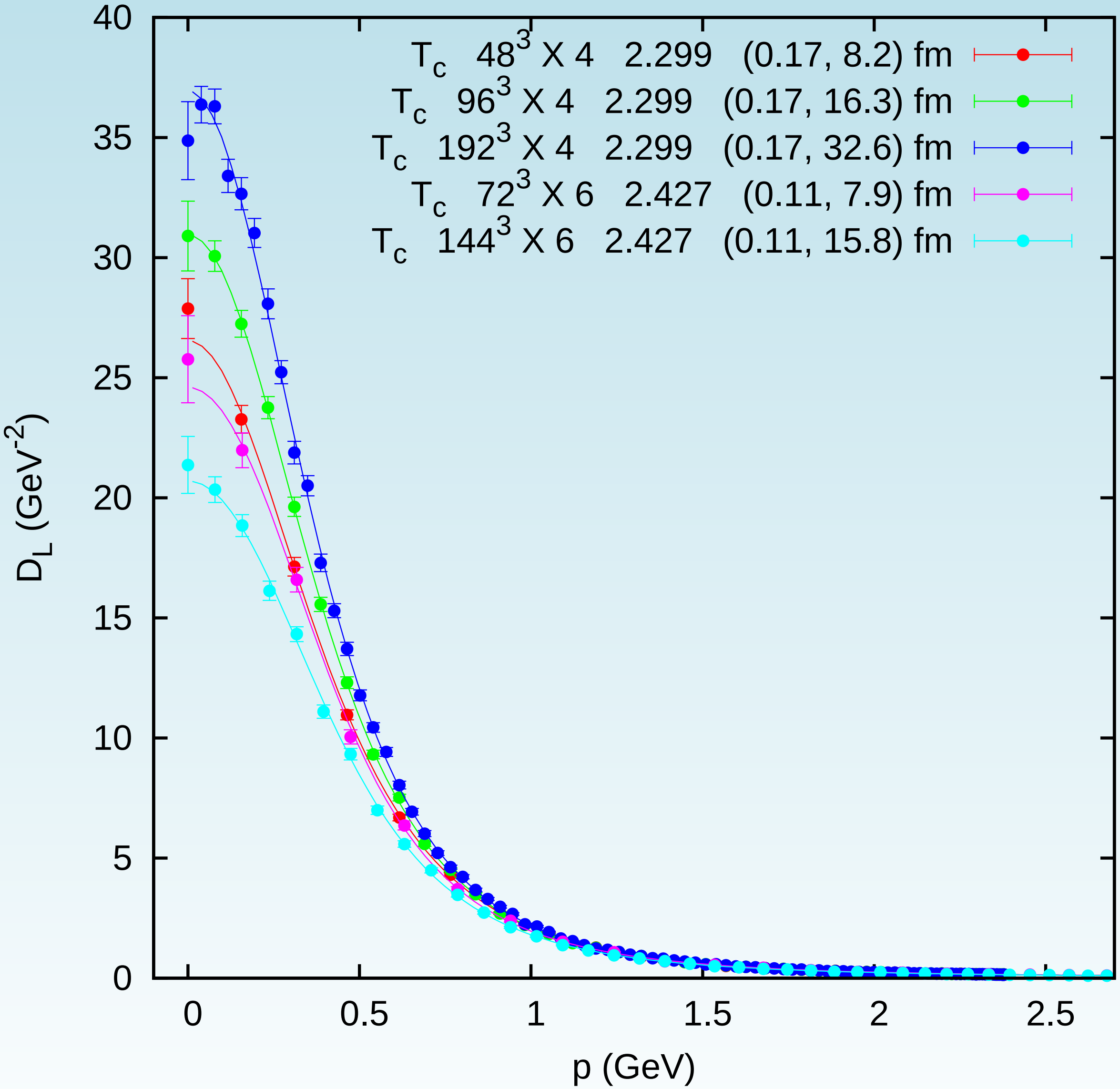

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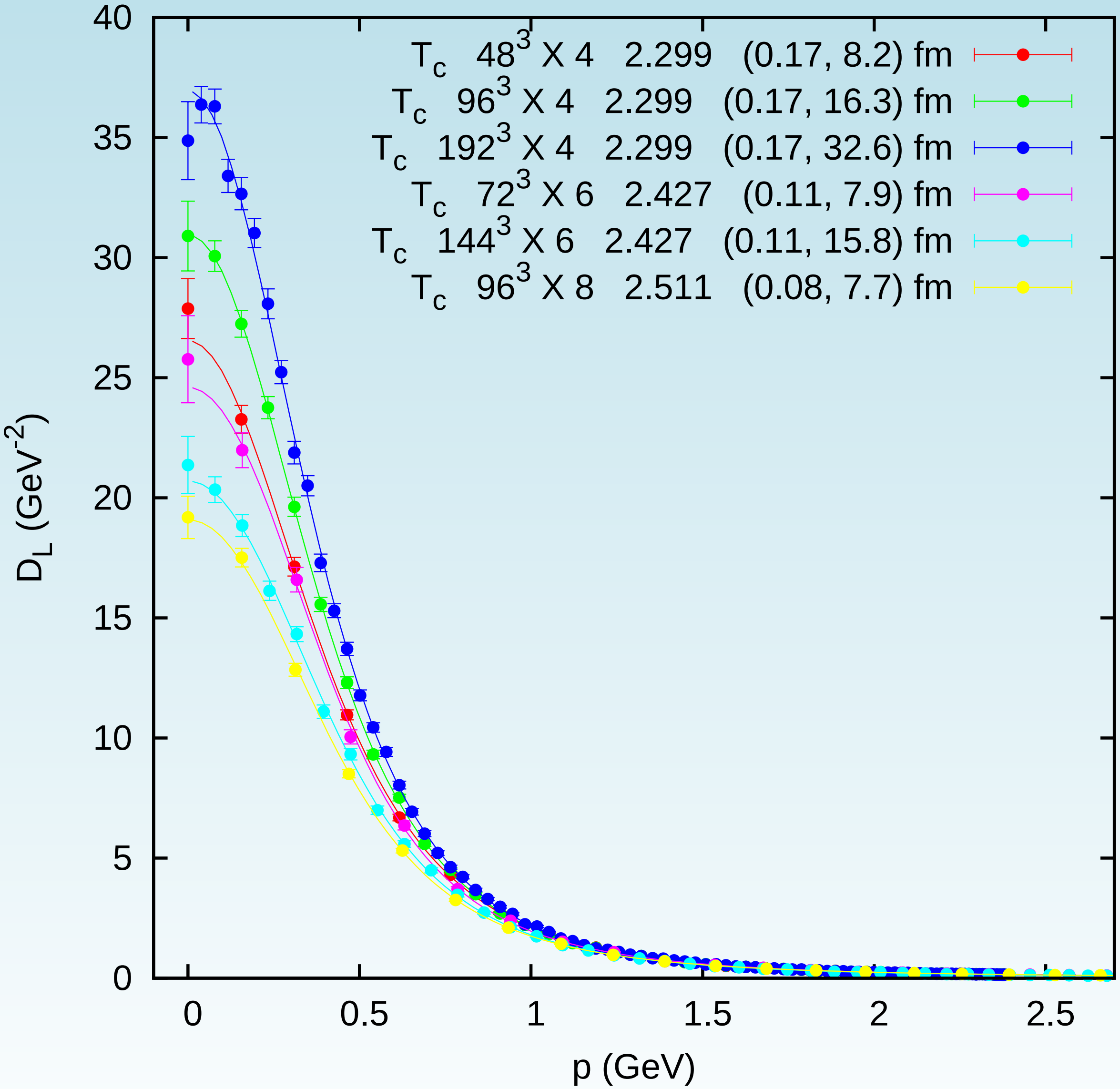

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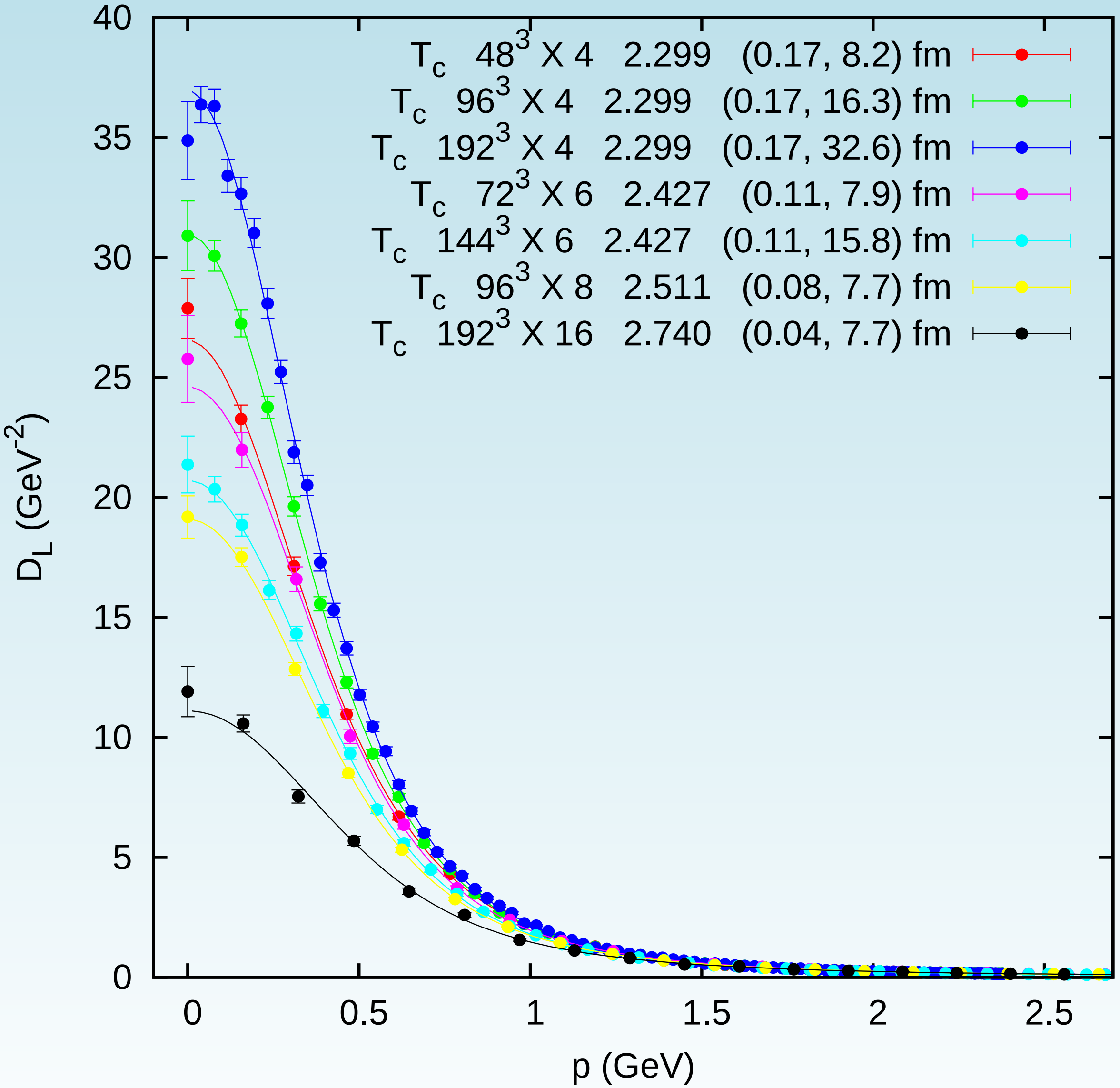
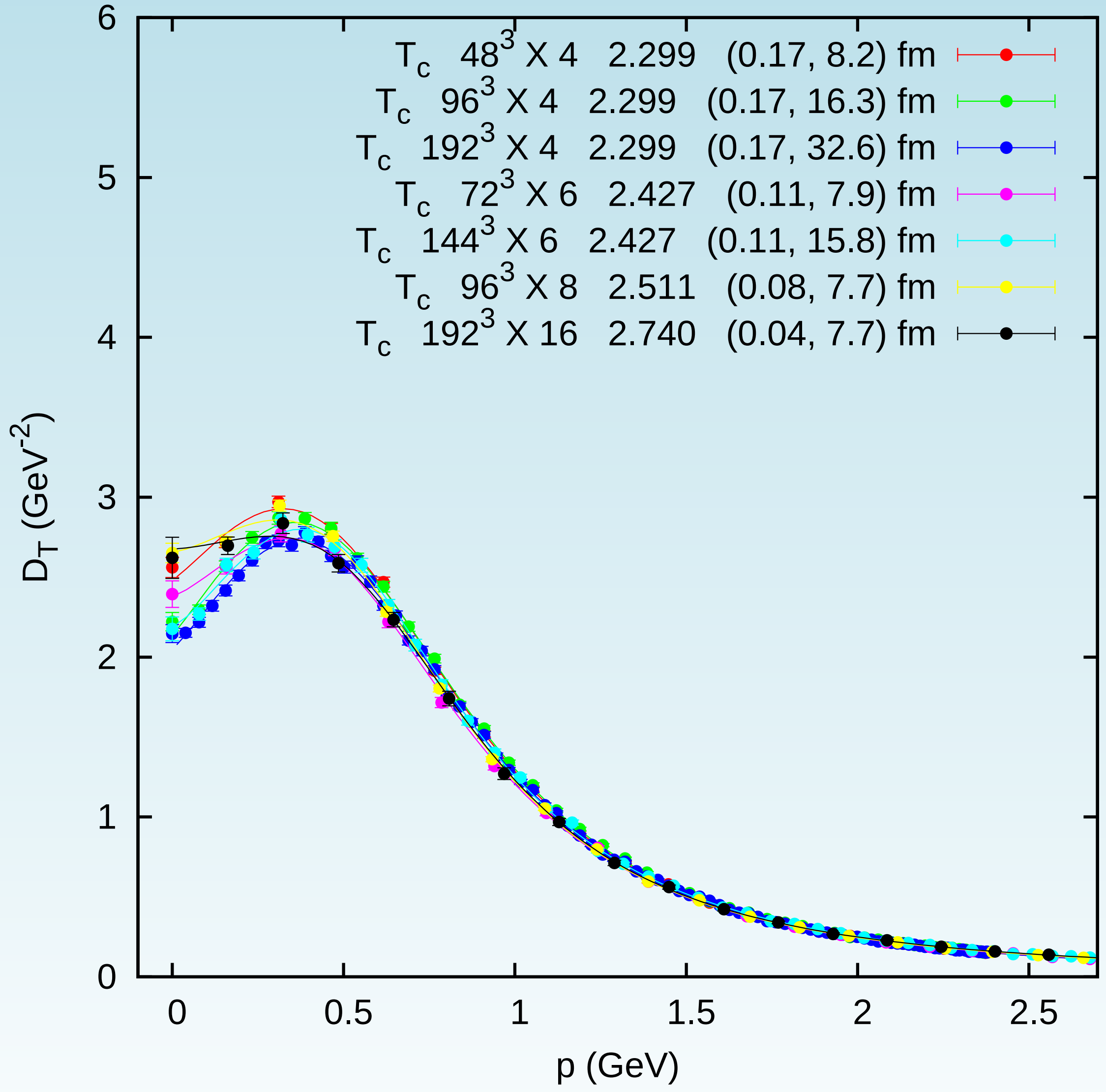
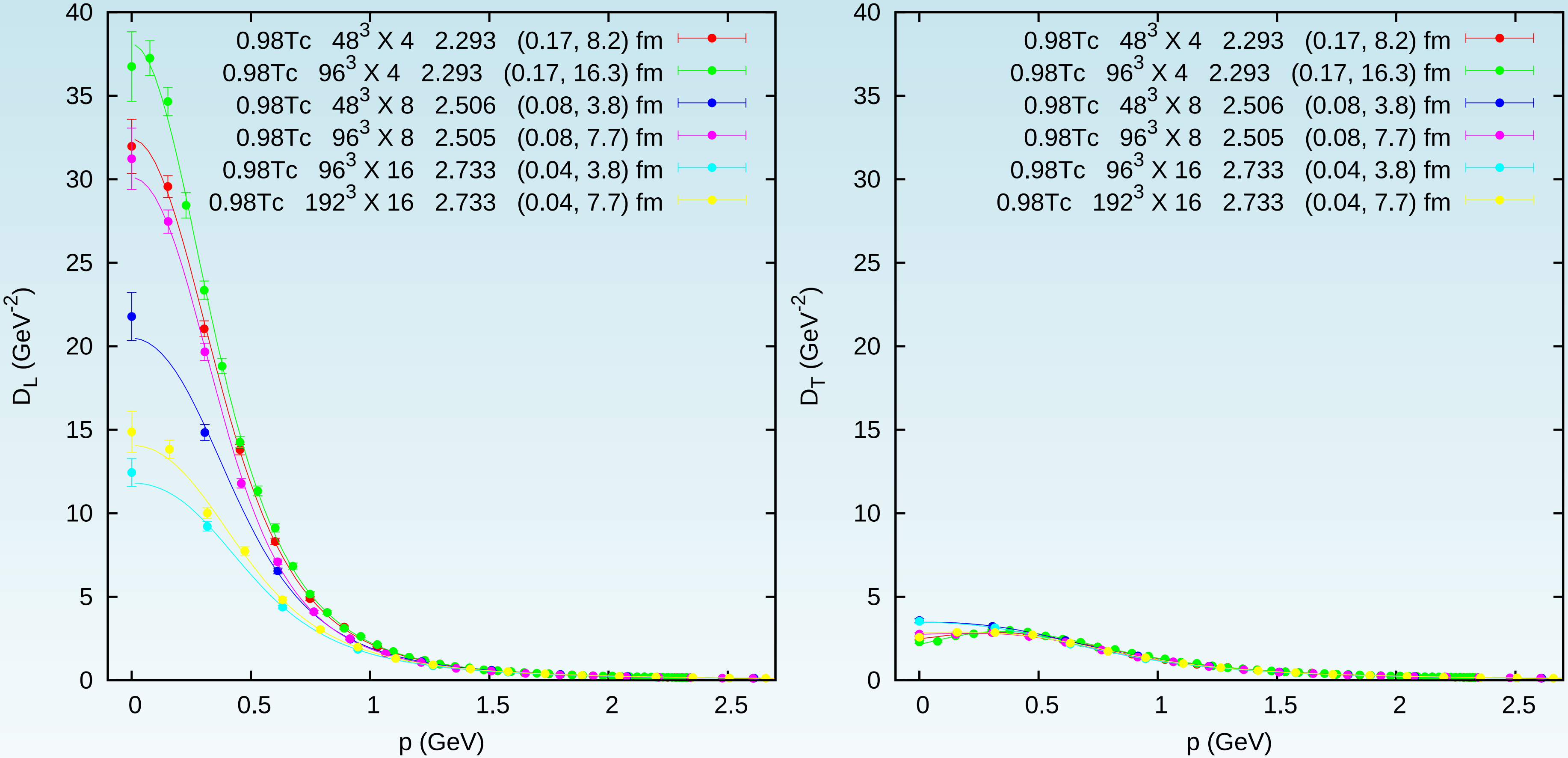


Results: Transverse Gluon at T_c



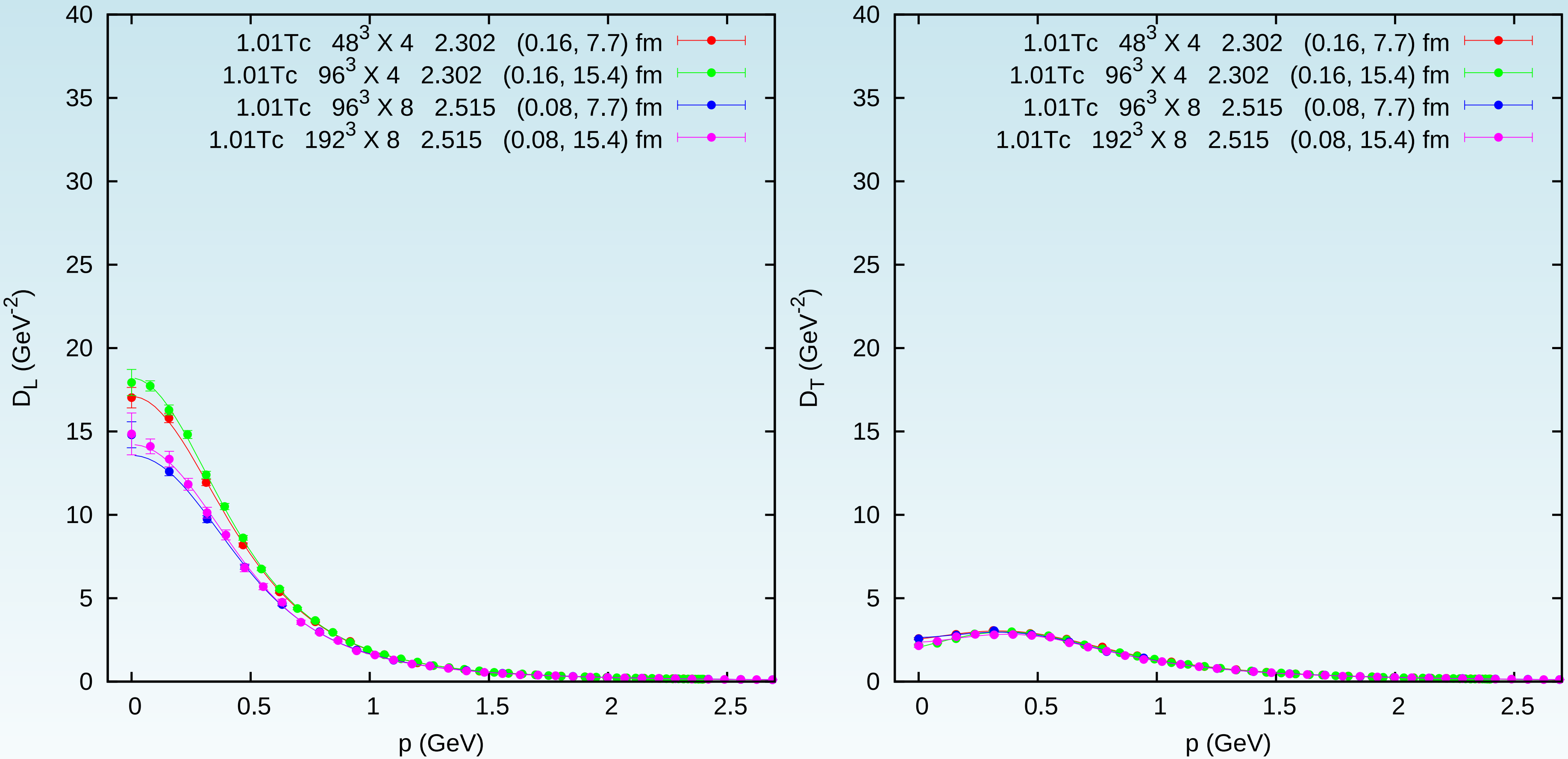
Results: Propagators at 0.98 T_c

Just below T_c, systematic errors for $D_L(p)$ are already present



Results: Propagators at 1.01 T_c

Just above T_c, systematic errors for $D_L(p)$ seem much less severe, IR plateau for $D_L(p)$ drops significantly for $N_t \leq 8$



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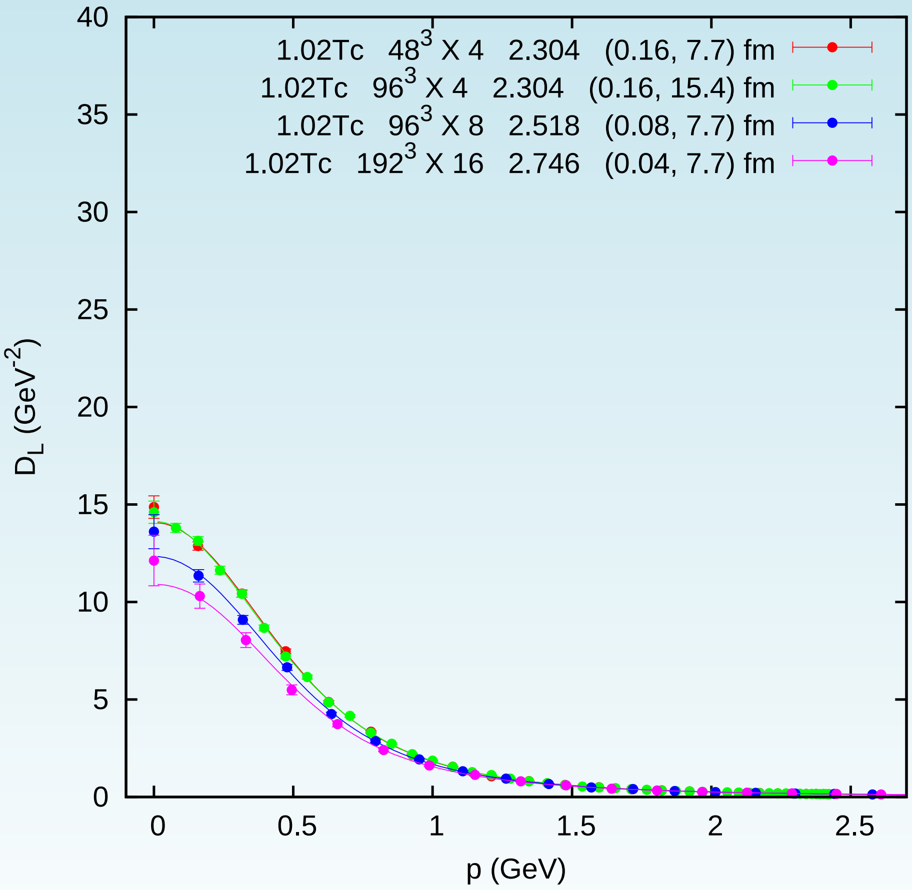
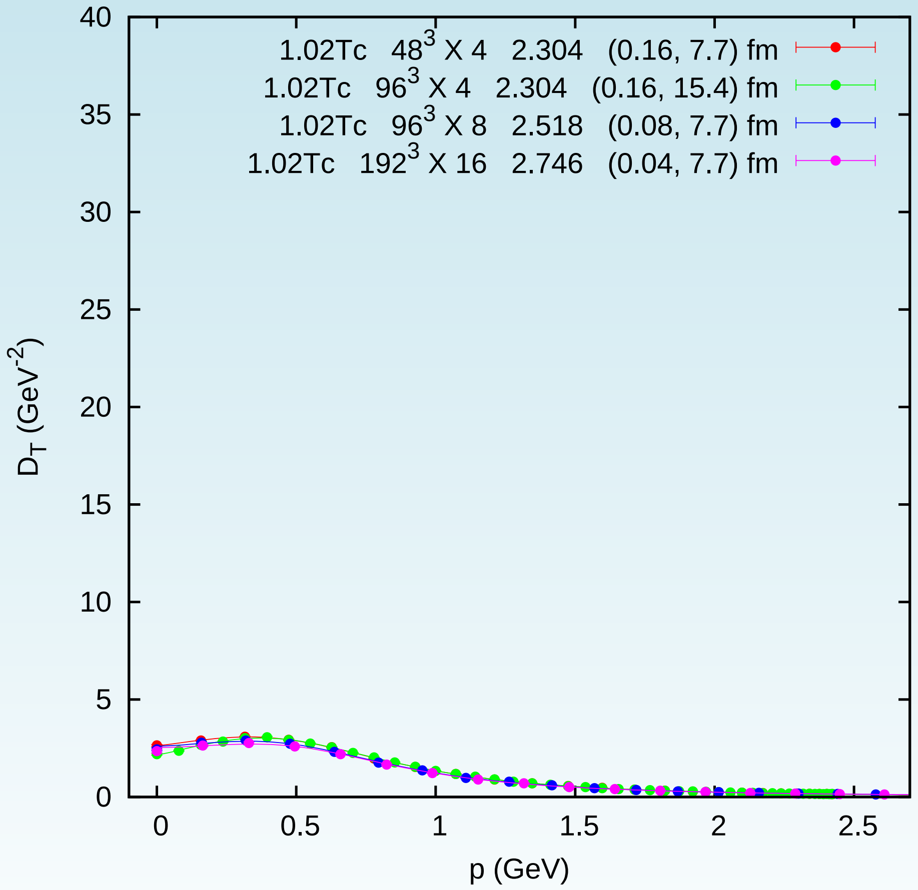
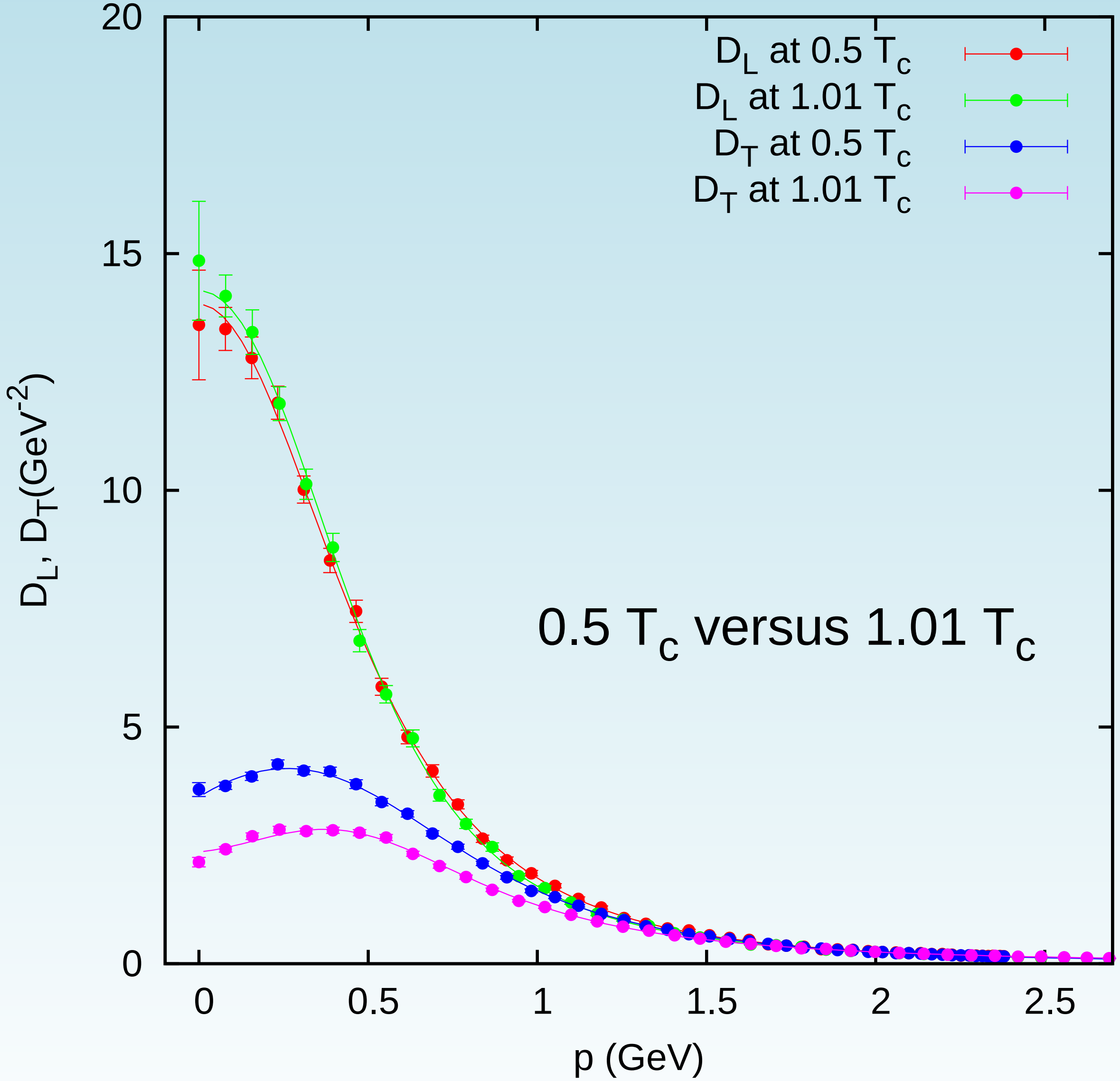




Comparison: $0.5T_c$ vs. T_c



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Clearly, the thing that stands out more about T_c is the presence of very large finite-size corrections, but the (large-volume) behavior of D_L itself seems to be smooth around the critical region

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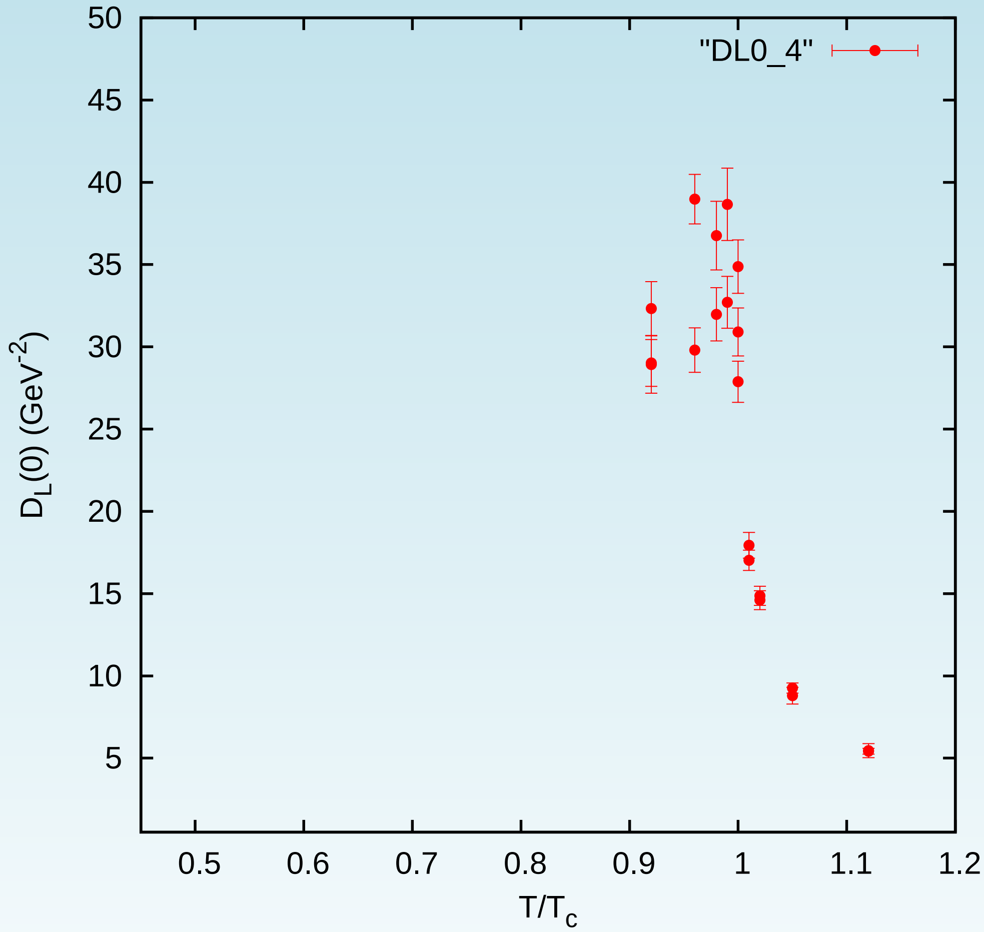
$\Rightarrow$ To get an idea let us consider $D_L(0)$ as a function of the temperature

Infrared Plateau for $D_L(p)$ vs. T

IR plateau [from $D_L(0)$]:



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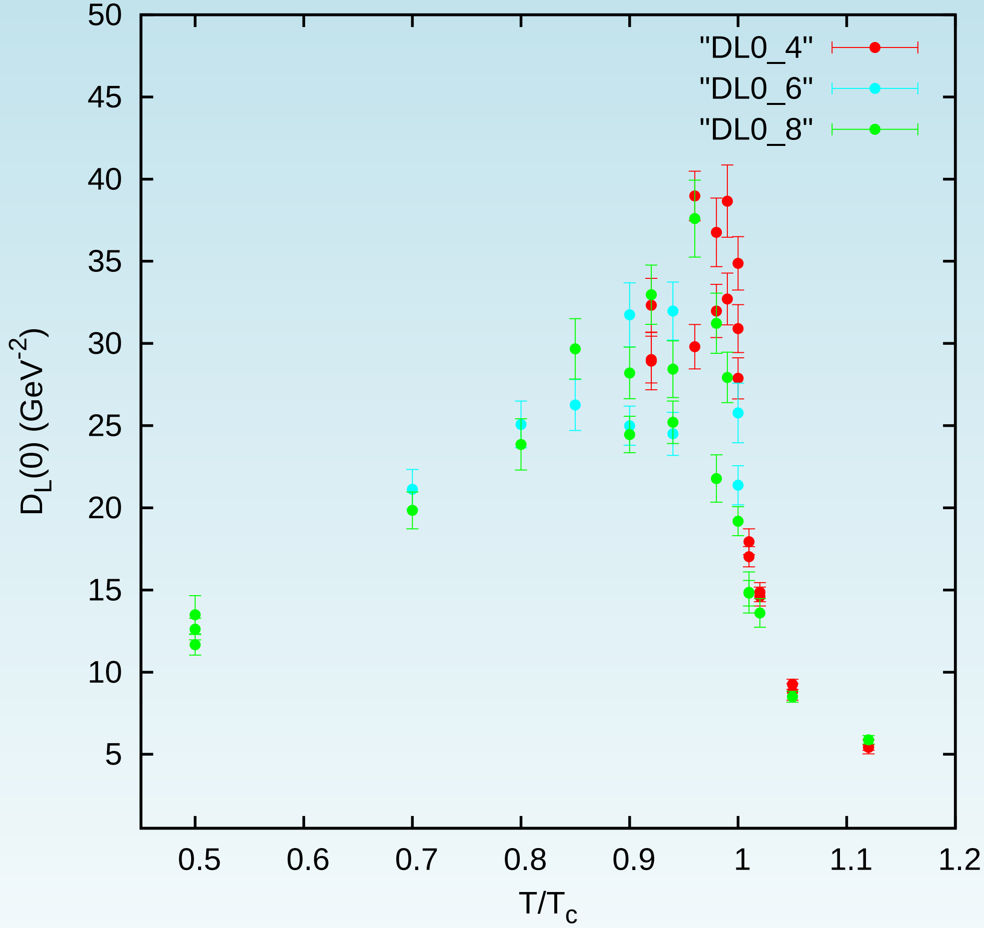

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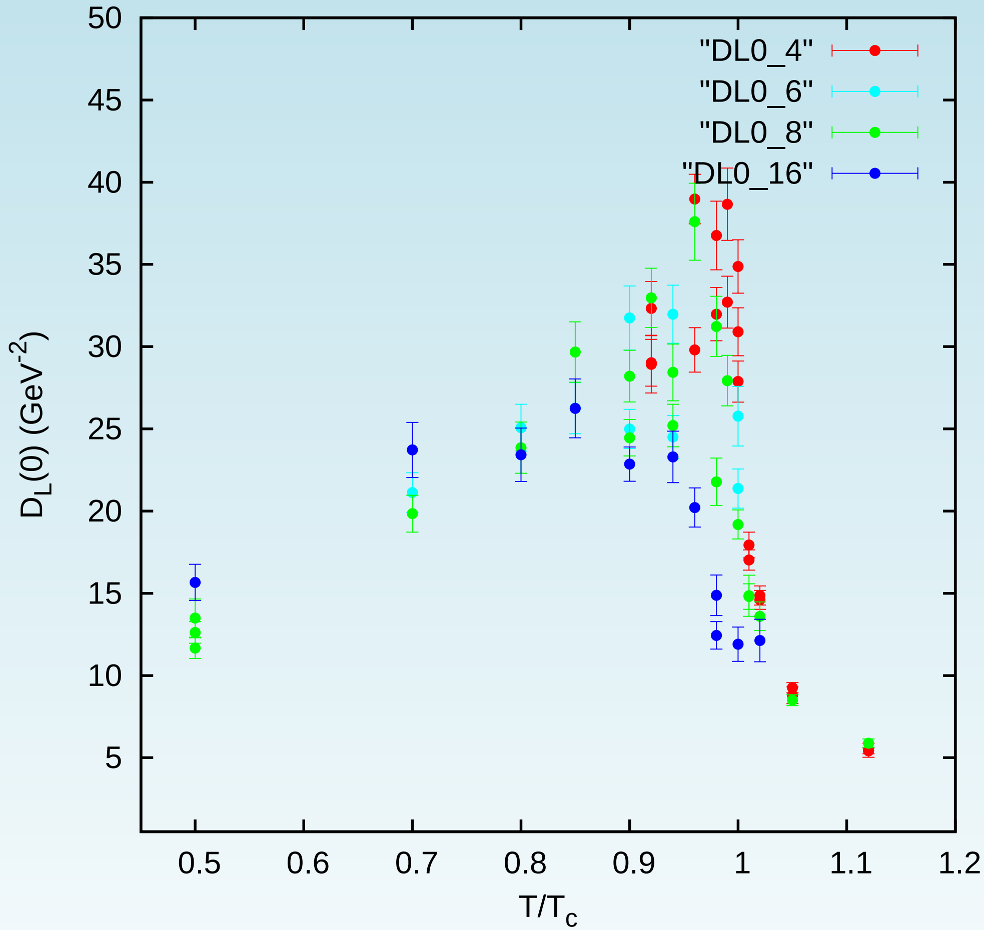

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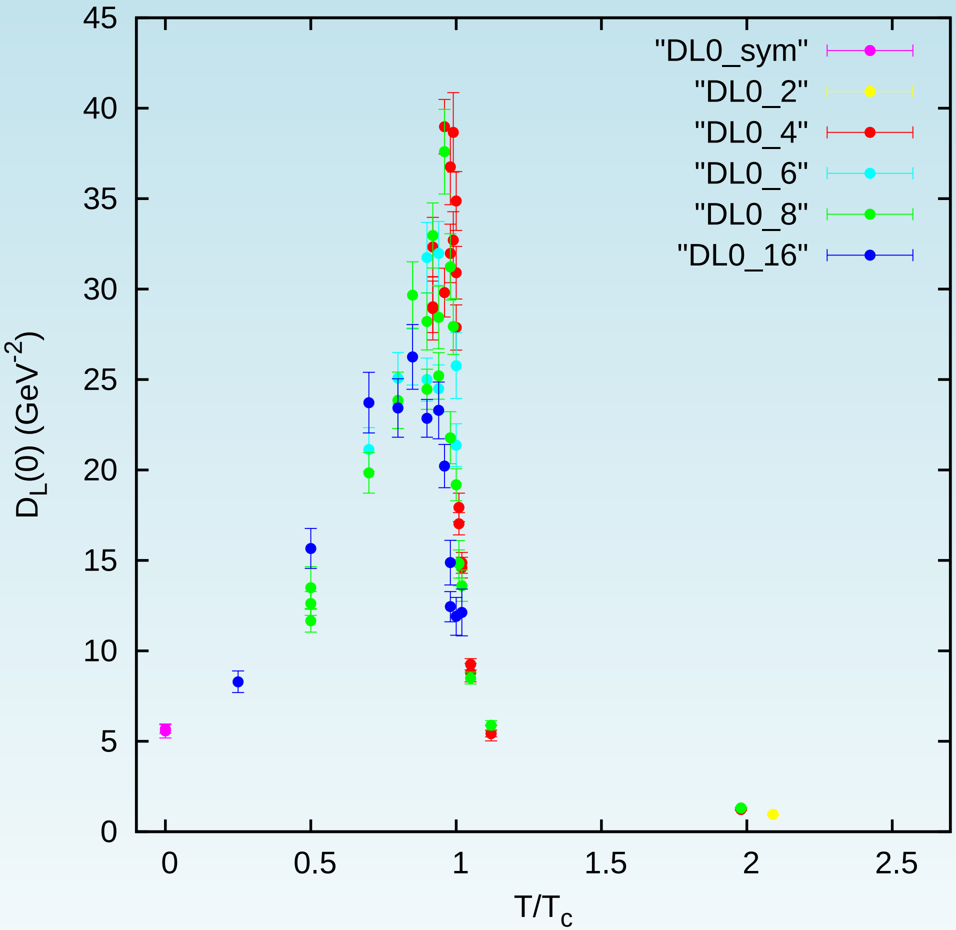
IR plateau [from $D_L(0)$]: all T



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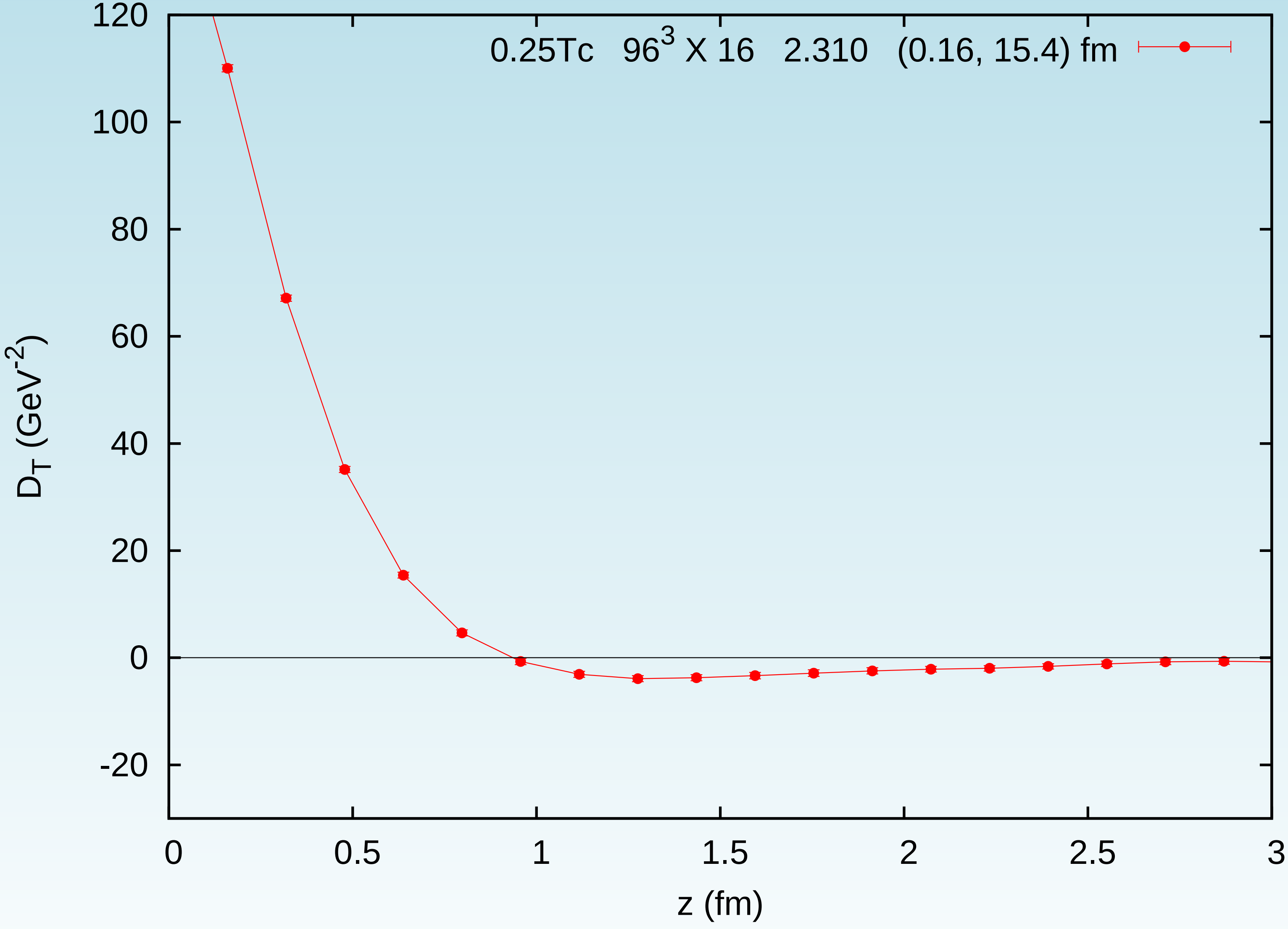
Electric and Magnetic Masses vs. T

T/T_c	$N_s^3 \times N_t$	$m_R^{(E)}$	$m_I^{(E)}$	$m_R^{(M)}$	$m_I^{(M)}$
0	$64^3 \times 64$	0.83 GeV	0.43 GeV	0.86 GeV	0.51 GeV
0.25	$96^3 \times 16$	0.61 GeV	0.28 GeV	0.57 GeV	0.28 GeV
0.5	$48^3 \times 8$	0.51 GeV	0.13 GeV	0.59 GeV	0.36 GeV
0.7	$96^3 \times 8$	0.31 GeV	0.13 GeV	0.37 GeV	0.24 GeV
0.9	$96^3 \times 16$	0.10 GeV	0.06 GeV	0.15 GeV	0.10 GeV
0.98	$96^3 \times 8$	0.19 GeV	0.10 GeV	0.28 GeV	0.20 GeV
1.0	$96^3 \times 8$	0.23 GeV	0.09 GeV	0.25 GeV	0.19 GeV
1.05	$96^3 \times 8$	0.29 GeV	0.09 GeV	0.24 GeV	0.18 GeV
2.0	$96^3 \times 8$	0.27 GeV	0.07 GeV	0.19 GeV	0.14 GeV

(Real-space) Transverse Gluon at $0.25T_c$



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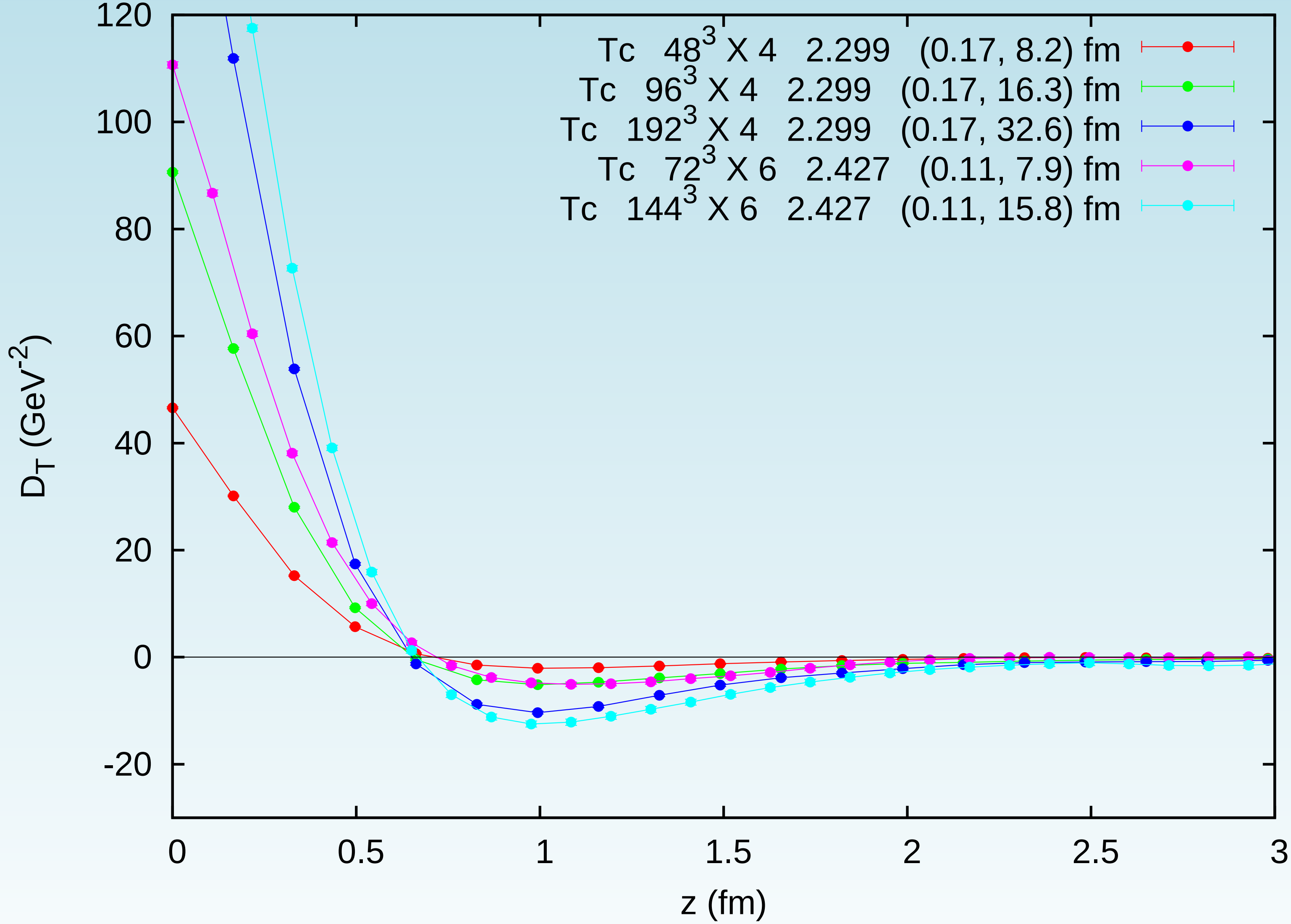
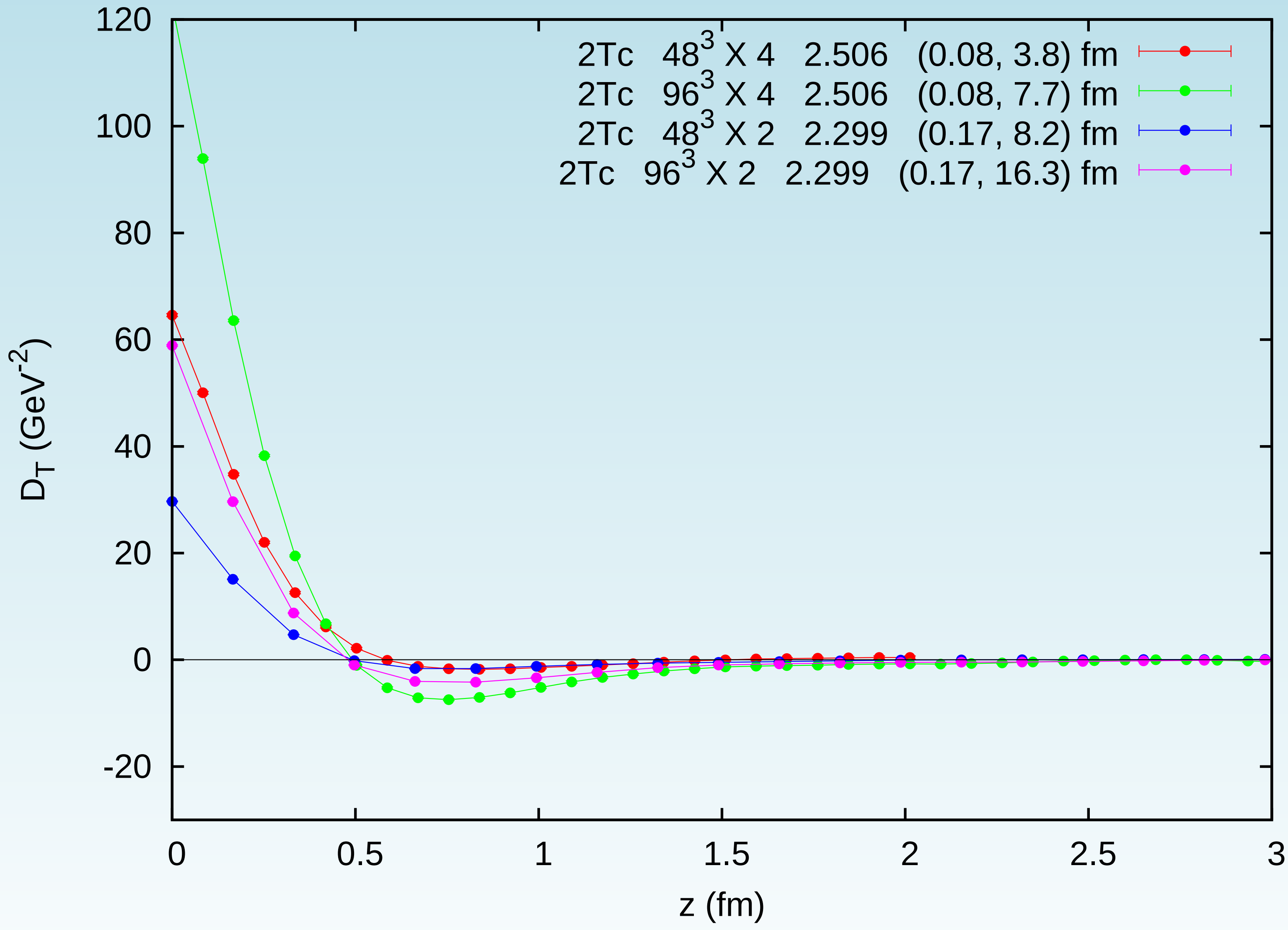


(Real-space) Transverse Gluon at $2T_c$



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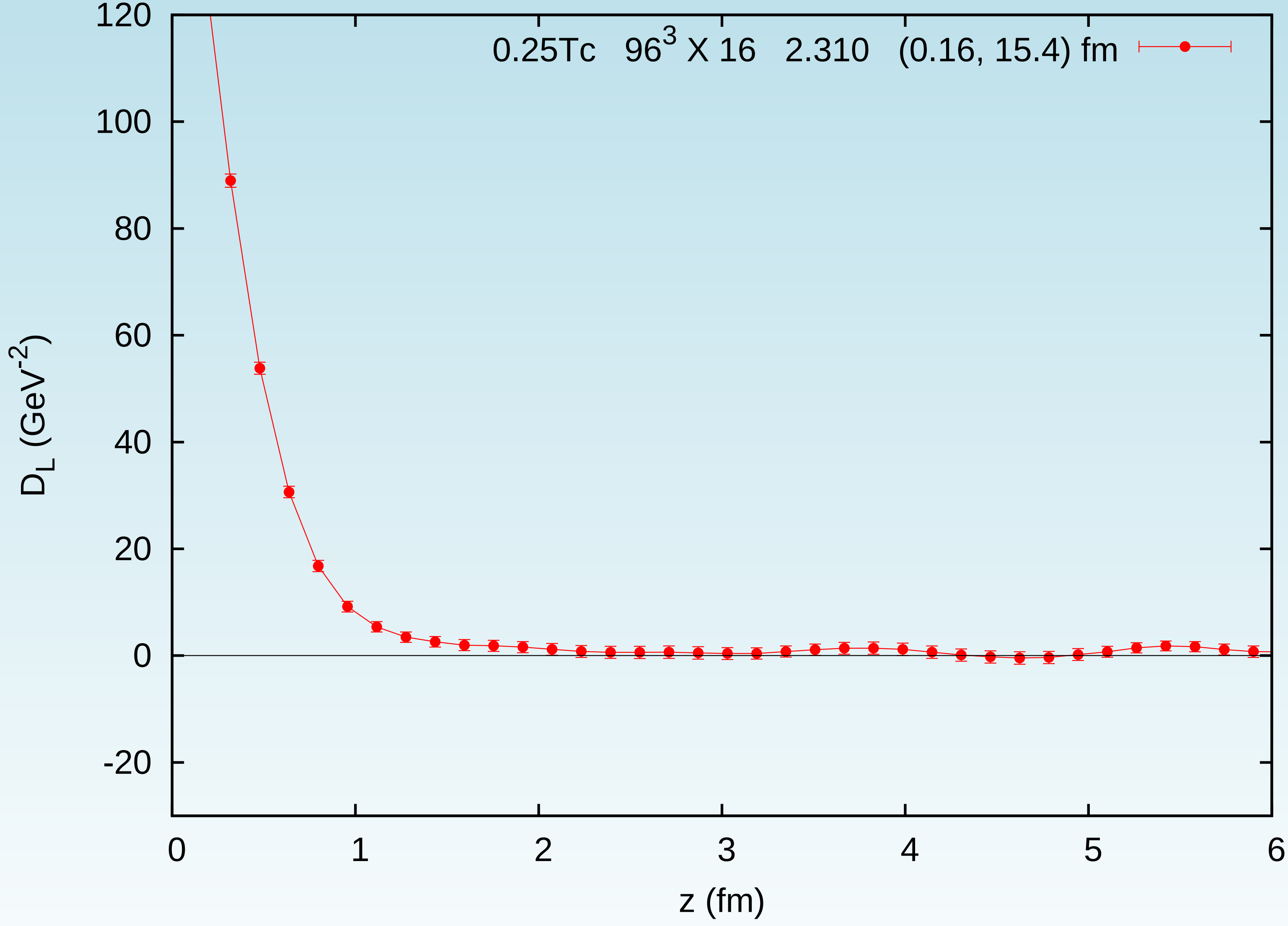

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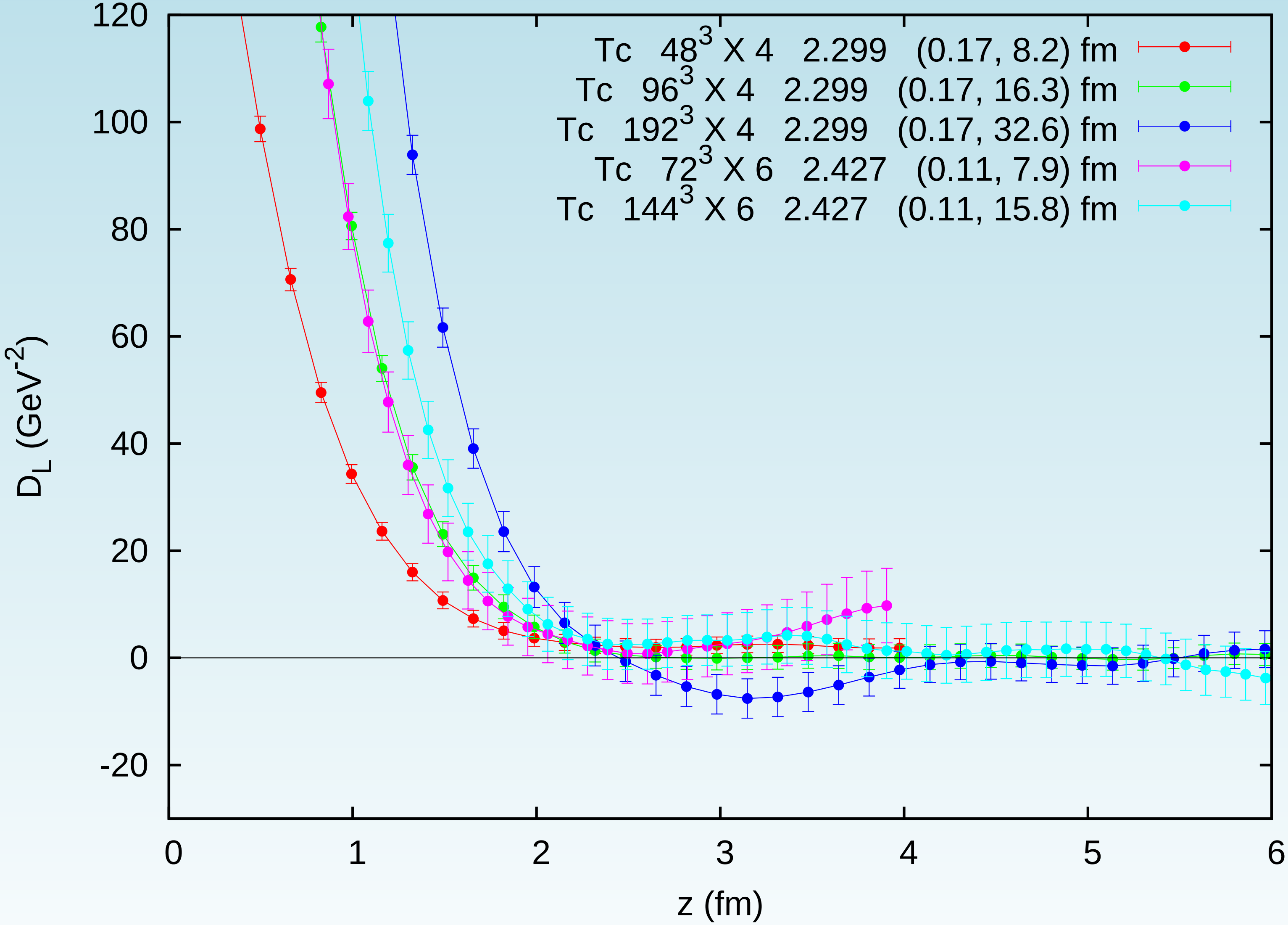

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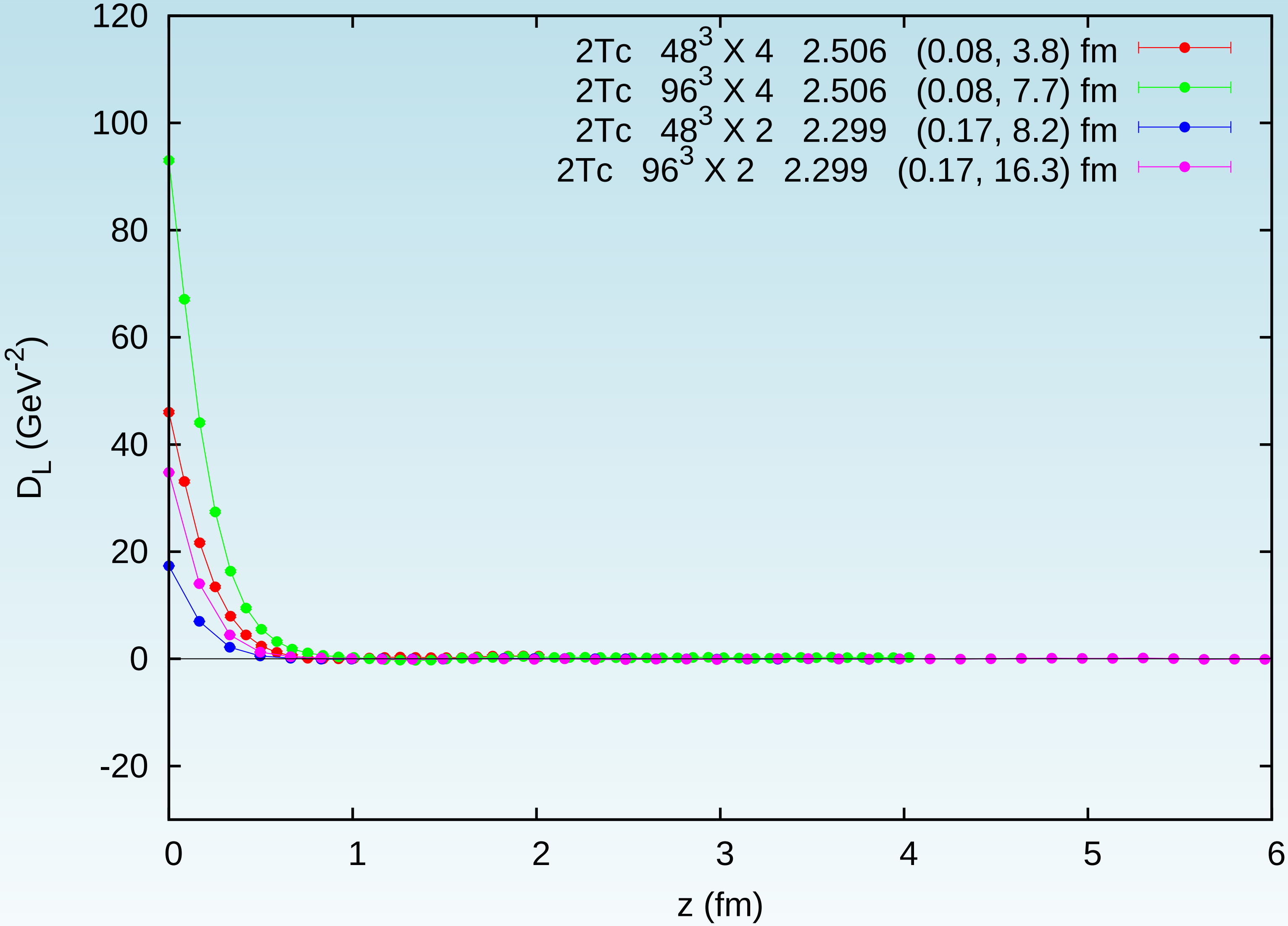

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Conclusions

- Transverse gluon propagator shows confinement: violates reflection positivity at all T; good fits to Gribov-Stingl form, with comparable real and imaginary parts of pole masses; turn-over in momentum at about 400 MeV; sizeable physical-volume effects; insensitive to transition $\Rightarrow$ (re)confirmation of dimensional-reduction picture (in agreement with other studies)
- Longitudinal gluon propagator: shows no violation of reflection positivity at all $T \neq 0$; masses from complex poles as opposed to $D_L(0)^{-1/2}$ (electric mass is also nontrivial); smooth around the transition; imaginary part seems to get smaller at higher T; severe systematic effects for $D_L(p)$ (volume dependence at fixed and small N_t) are strongest at the critical point; large-lattice (and $N_t > 8$) results indicate no singularity of IR plateau; peak turns into a bump, to the left of T_c... $\Rightarrow$ previously seen peak of $D_L(0)$ at T_c produced by freakishly large systematic effects