Unbearable Lattice of Being

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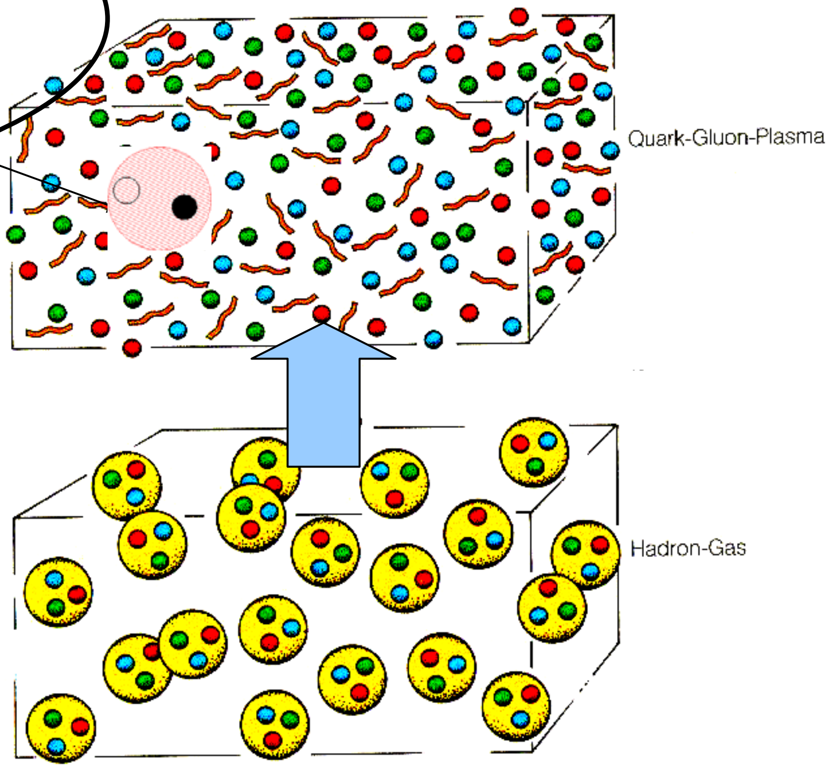
How strong the interaction of quarks in QGP ?
Can heavy quarks be bound at $T > T_{dec}$?

signature of QGP at RHIC
(quarkonium suppression)

Quark Gluon Plasma →

Deconfinement transition
$T_{dec} = 170 - 180$ MeV

Hadron Gas →




The Lattice

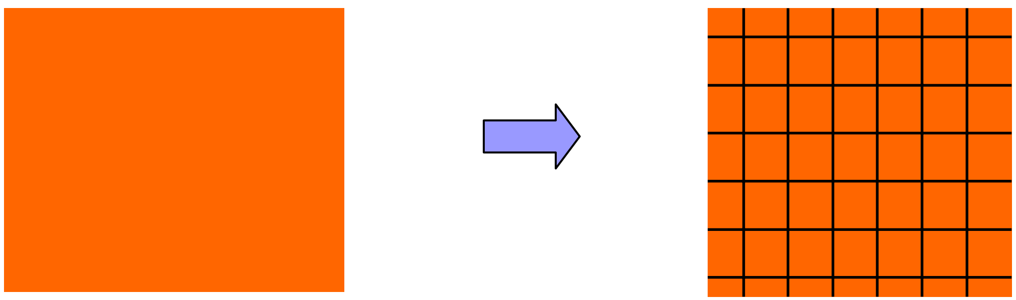
Lattice Quantum ChromoDynamics (LQCD)

- Expectation values of observable *O* at temperature T

$$< O > = \int DA_\mu D\overline{\psi} D\psi \exp(-S_{QCD}),$$

$$S_{QCD} = \int_0^{1/T} d\tau \int d^3x \left(\frac{1}{4} {F_{\mu\nu}^a}^2 + \overline{\psi}^a (D_\mu \gamma_\mu - m) \psi^a \right)$$

- Discretization of the Euclidean space-time, QCD ⇒ LQCD



⇒ Finite but very large $(> 10^4)$ dimensional integral

⇓

Numerical Monte-Carlo simulations on massively parallel supercomputers

QCDOC supercomputer

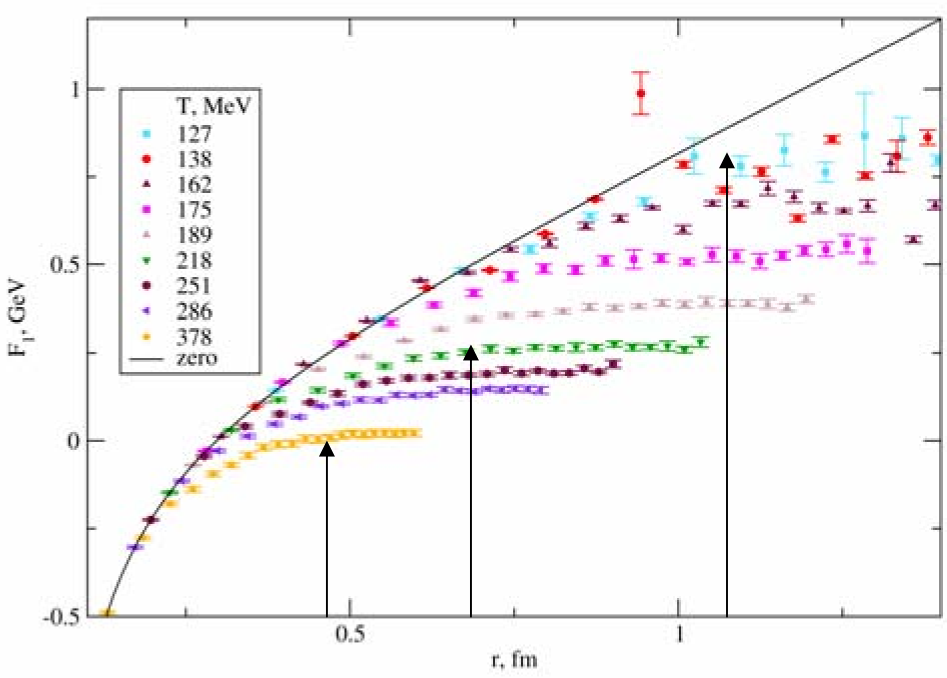
- 30Tflops combined / 15Tflops sust.
- Built by physisists – for QCD
- UKQCD, RIKEN, DOE own 1/3 each
- Up and running
- Zero and Finite temperature runs

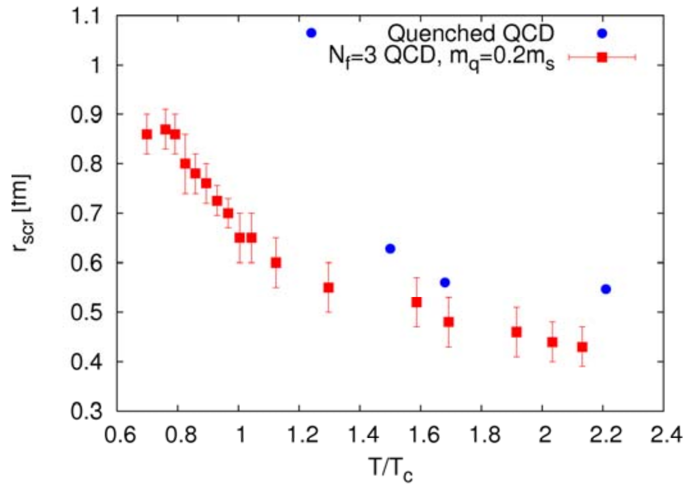
Modification of Inter-quark Forces at Finite Temperature

Potential between static quark and anti-quark $Q\bar{Q}$ at $T = 0$

Free energy of static $Q\bar{Q}$ at $T > T_{dec}$

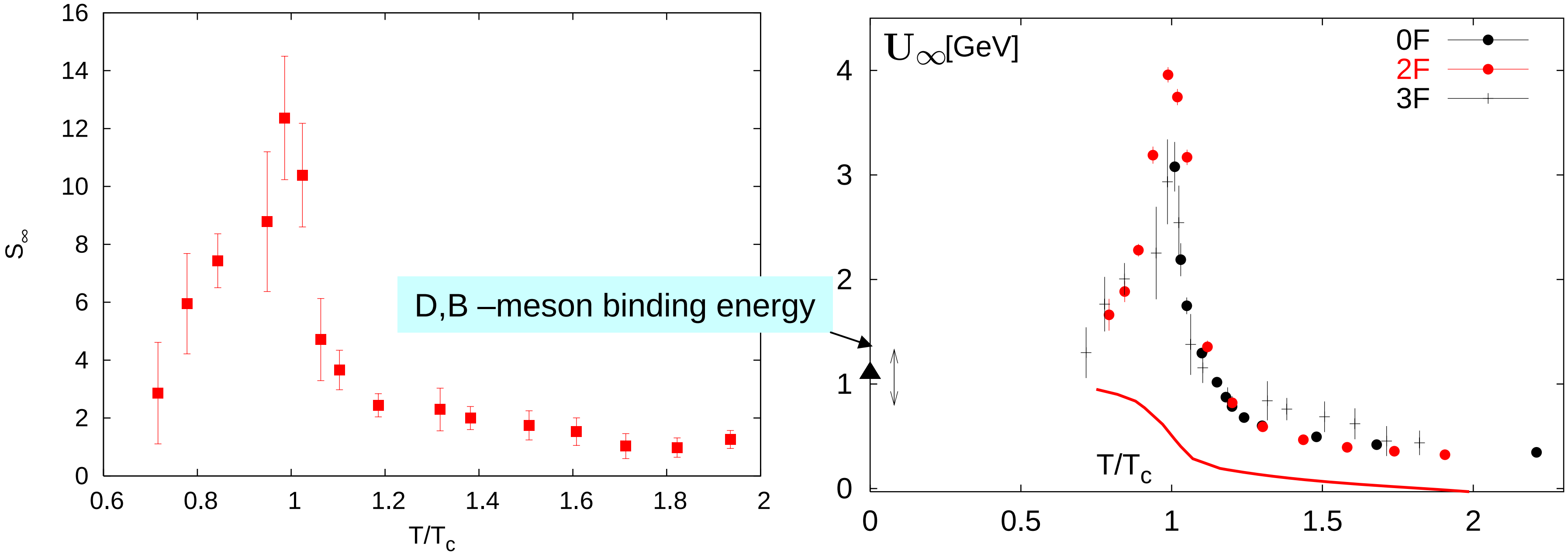
$$V(r) = -\frac{4}{3}\frac{\alpha_s}{r} + \sigma r \quad \Rightarrow \quad F(r,T) = -\frac{4}{3}\frac{\alpha_s}{r} \cdot e^{-r/r_{scr}(T)} + C(T)$$





K. P., P.Petreczky, Phys.Rev. D70 (04) 054503

There is a large increase in the entropy and internal energy at the transition temperature !



K. P., P.Petreczky, PRD 70 (04) 054503

extra static meson increases the entropy and the internal energy

Quarkonium Spectral Functions

$$\frac{dW}{d\omega d^3 p} = \frac{5\alpha^2}{27\pi^2} \cdot \frac{1}{\omega^2 (e^{\omega/T} - 1)} \sigma_V(\omega, \vec{p})$$

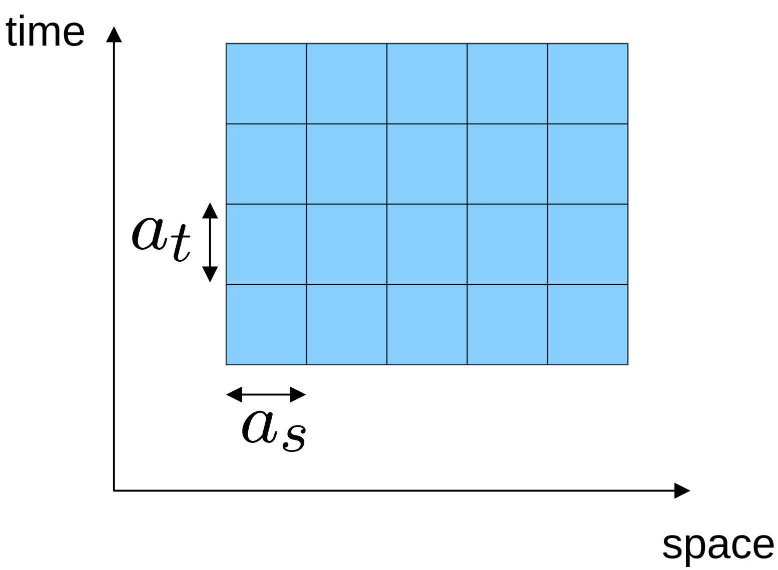
$$\int_0^\infty d\omega \sigma_V(\omega, \vec{p}) \frac{\cosh(\omega(\tau - 1/(2T)))}{\sinh(\omega/(2T))} = G(\tau, \vec{p})$$

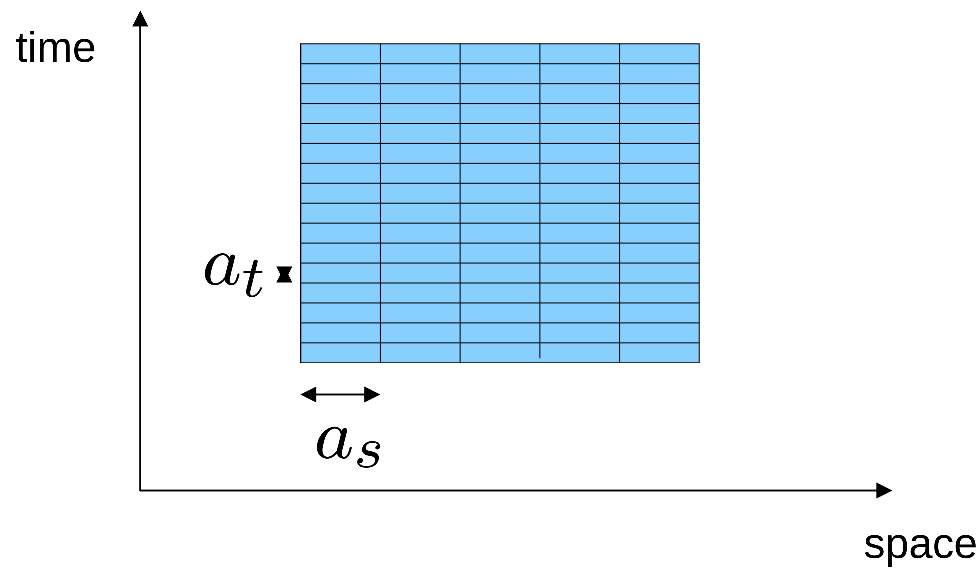
experiment

Maximum Entropy Method (MEM)

LQCD

Large number of data points for $G(\tau, p)$ → anisotropic lattice



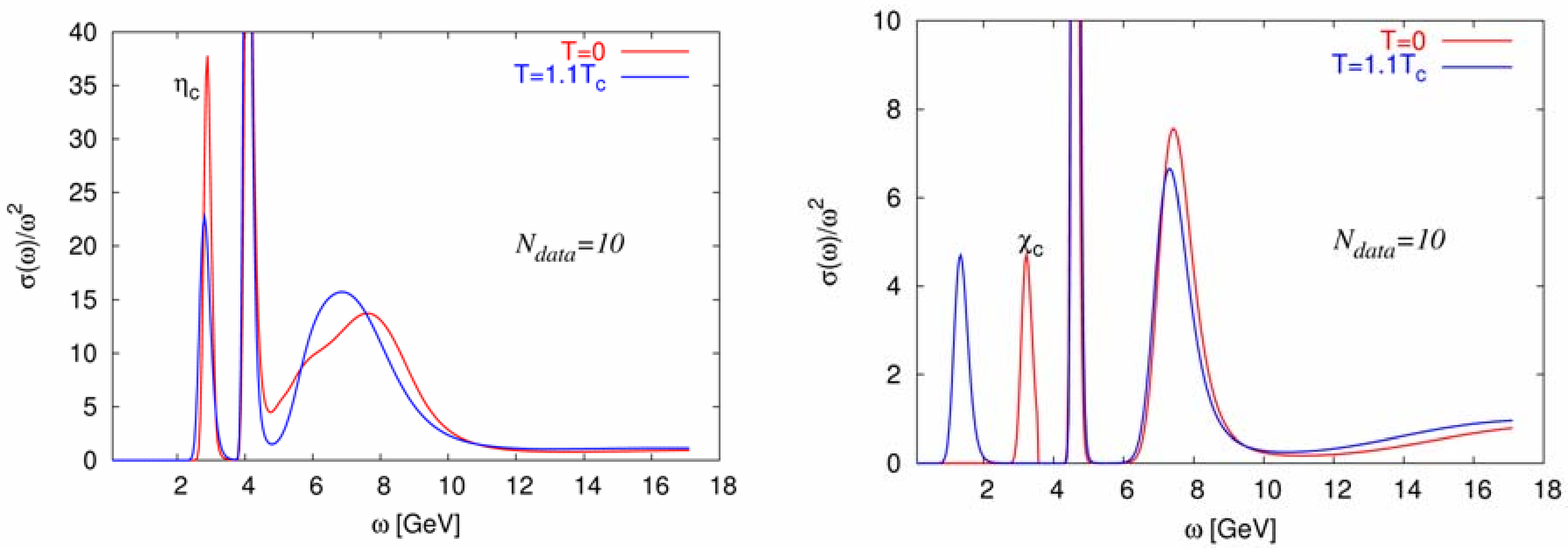


Numerical Results on Quarkonium Spectral Functions

Recent results from anisotropic lattices:

Fermilab action $a_s = 0.01\mathrm{fm}$ $a_s/a_t = 4,\ 16^3 \times N_t,\ N_t = 96,\ 24$

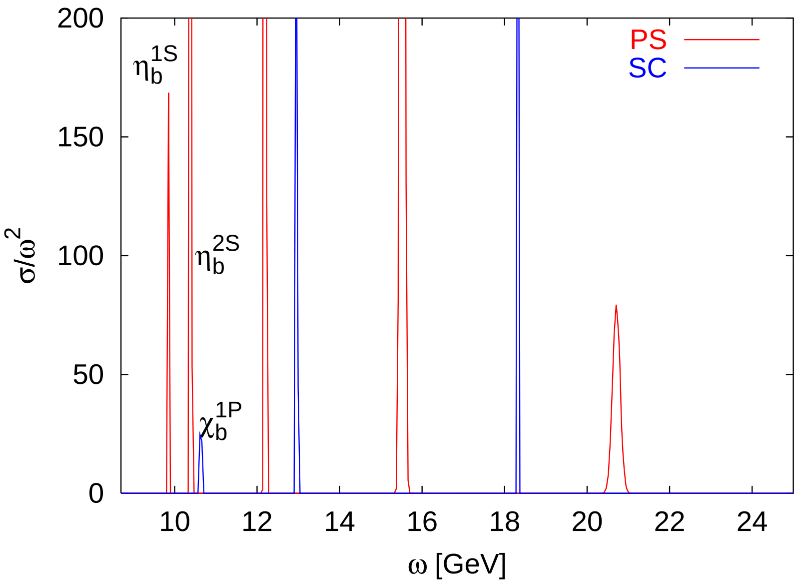
$1S$ state survives $1P$ state dissolved



P.Petreczky, K. P., A. Velytsky, work in progress

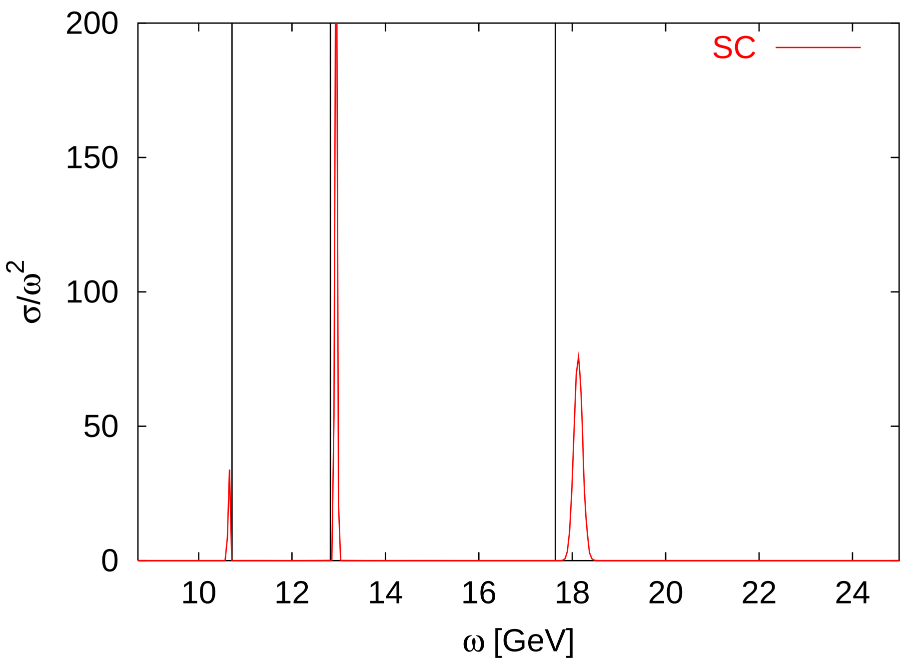
calculations on 1st QCDOC supercomputer prototypes

Bottomonia spectral functions at T=0



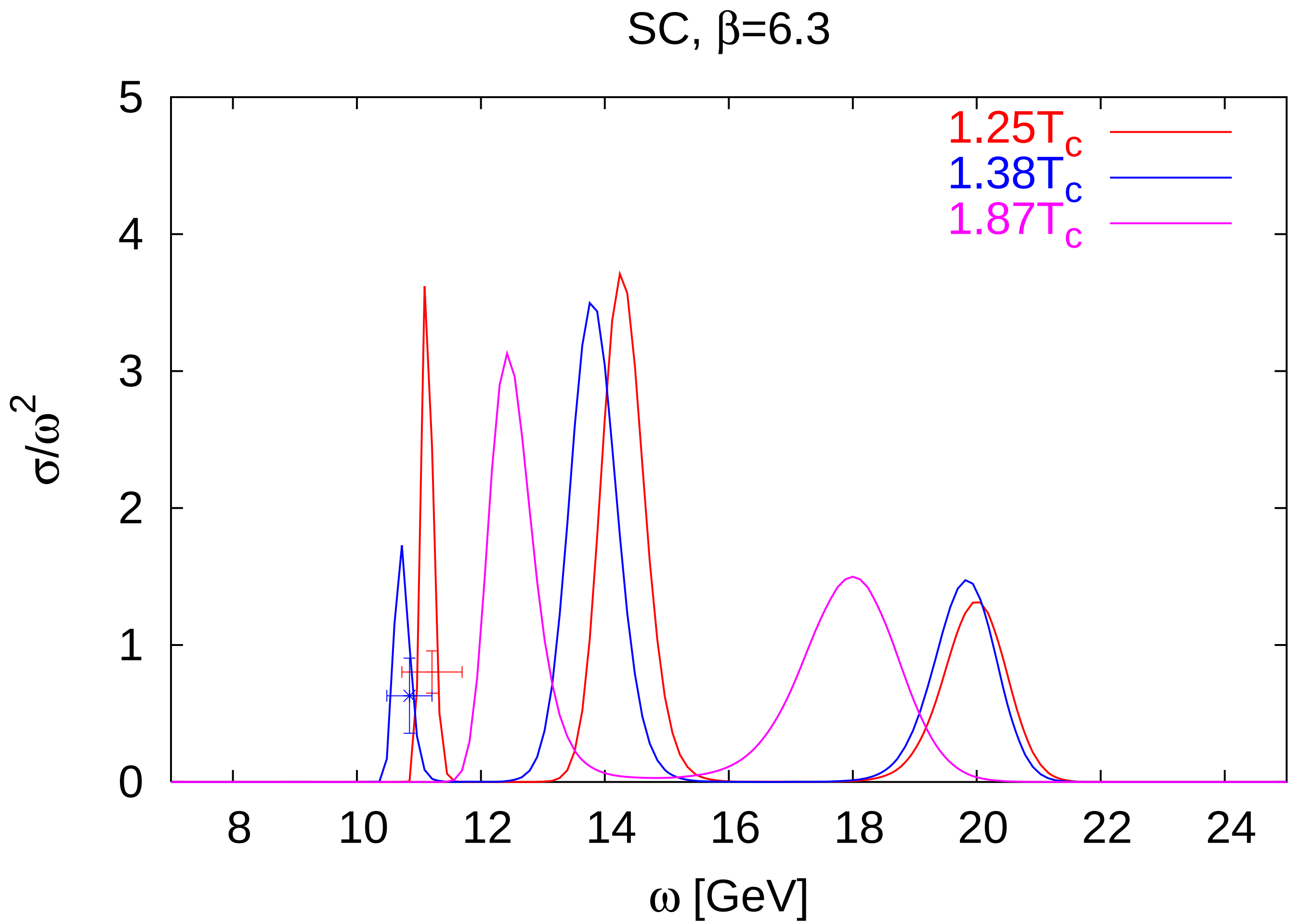
Excited 1P and 2S bottomonia states are identified.

Peaks at $\omega > 12\text{GeV}$ are presumably lattice artifacts.



Consistency between constrained curve fitting and MEM

Does 1P bottomonium state exists in the plasma ?



LHC Exit Strategy

- What if perturbation theory fails?
- Need Plan B
- Non-perturbative effects in EW sector?
- No Lattice formulation of EW
- Fermions in Two-index representation with Technicolor
- New Terrain

Summary

- Lattice works
- Hands-on Lab on symmetry breaking
- Lots of thermodynamics and zero temperature results
- Early spectroscopy from first principles
- Use elsewhere – especially when desperate