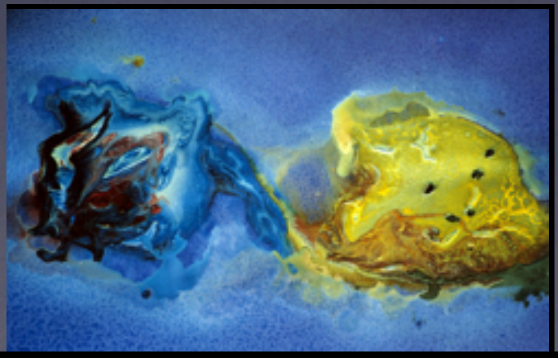
Heavy Quarkonium at Finite Temperature

Nora Brambilla



Physik Department TUM
T30f

Content

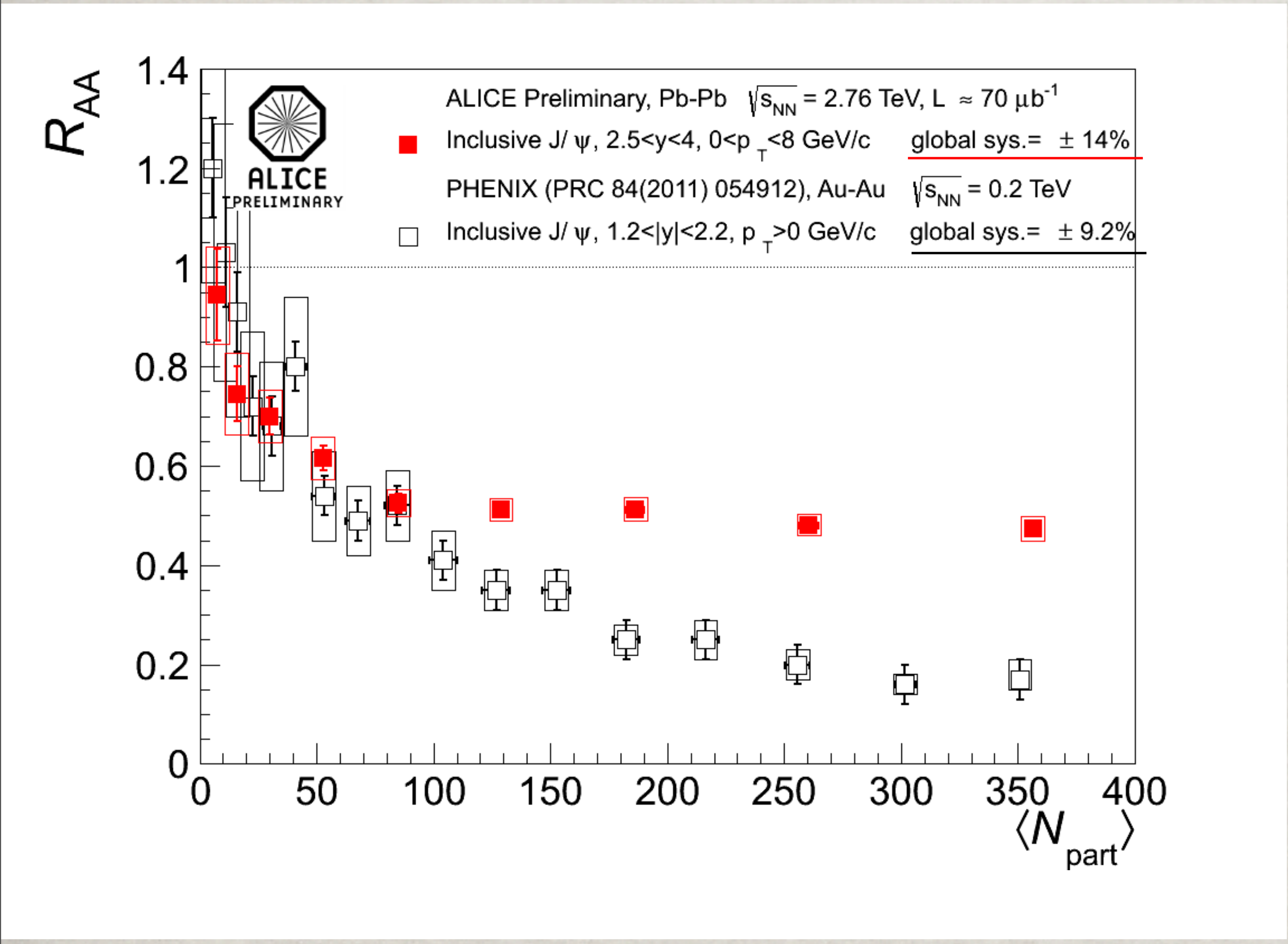
- quarkonium interaction in the hot medium

- effective field theory calculation of the potential, setting up of a calculational framework

- physical implications and discussion of the physical picture

- application to the Y(1S) at LHC

Quarkonium suppression is believed to be a probe of QGP formation



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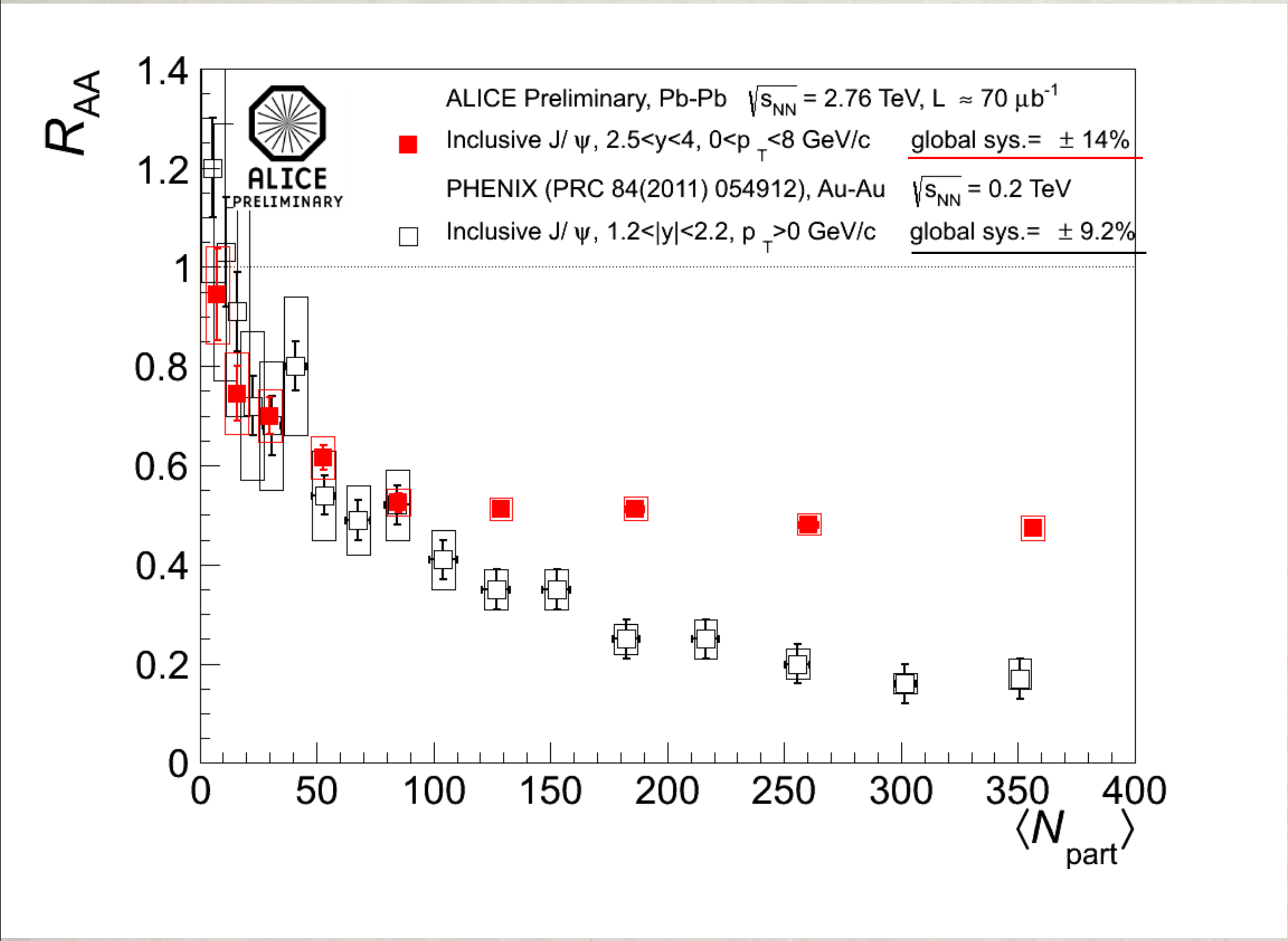

A quantitative understanding of suppression calls for understanding of

- In-medium production and cold nuclear matter effects
- In-medium bound-state dynamics
- Recombination effects

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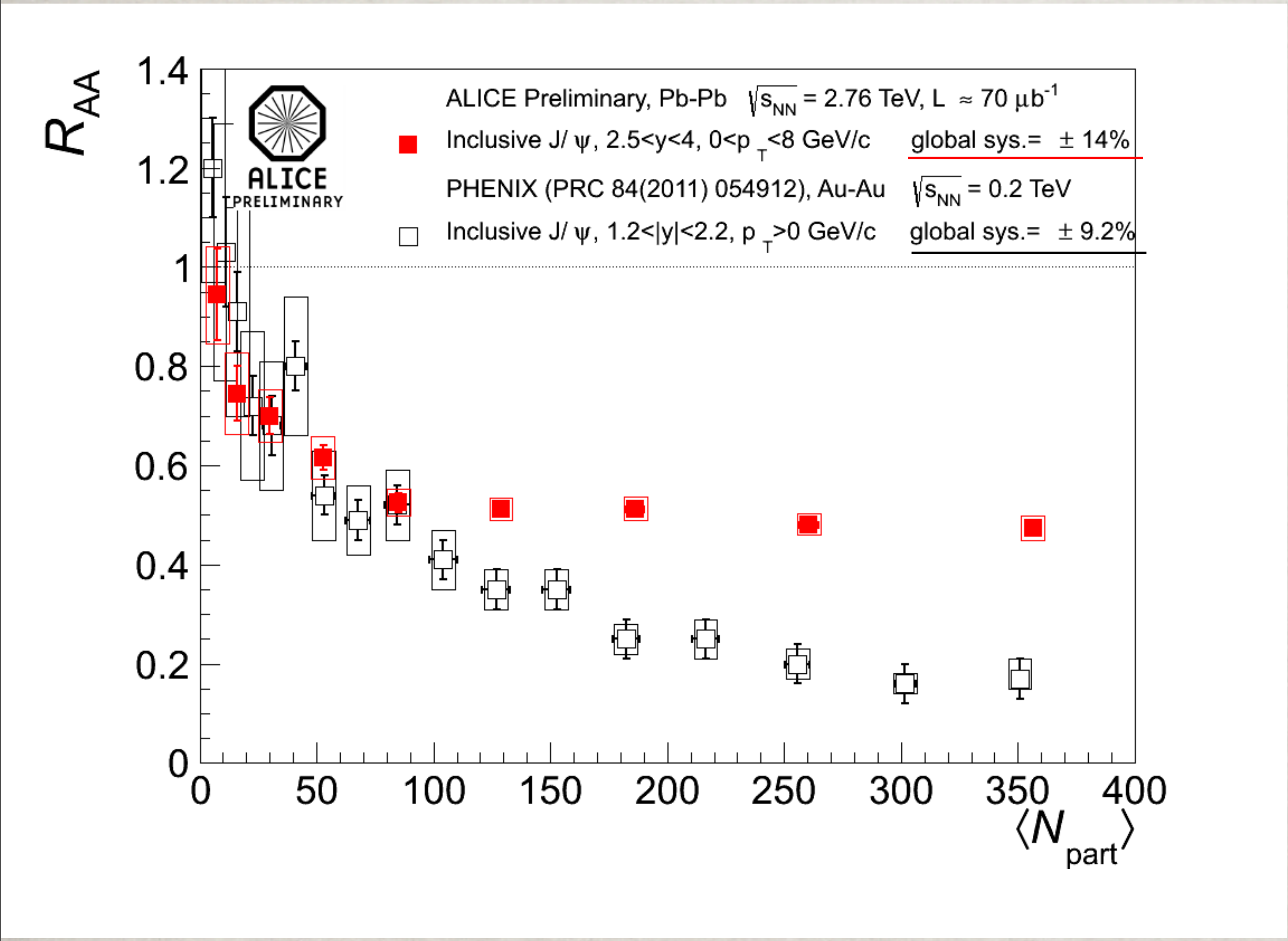

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Quarkonium suppression in the hot medium due to color screening

Volume 178, number 4 PHYSICS LETTERS B 9 October 1986

J/ψ SUPPRESSION BY QUARK–GLUON PLASMA FORMATION ☆

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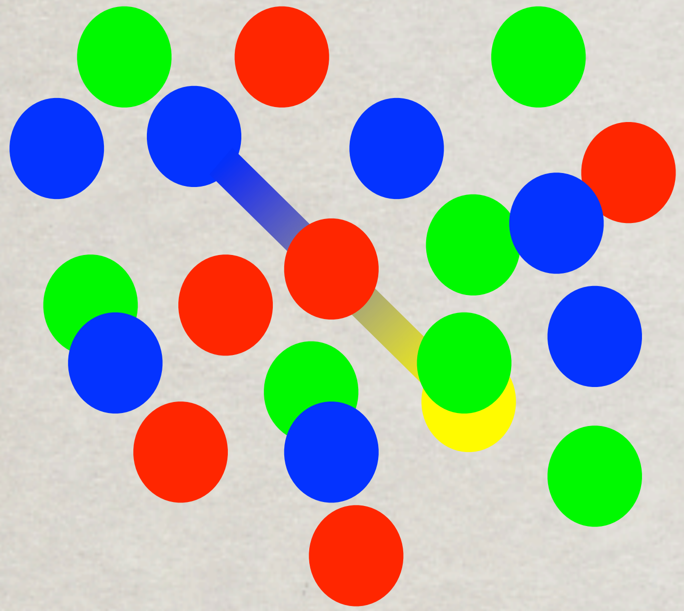
Received 17 July 1986

If high energy heavy ion collisions lead to the formation of a hot quark–gluon plasma, then colour screening prevents $c\bar{c}$ binding in the deconfined interior of the interaction region. To study this effect, the temperature dependence of the screening radius, as obtained from lattice QCD, is compared with the J/ψ radius calculated in charmonium models. The feasibility to detect this effect clearly in the dilepton mass spectrum is examined. It is concluded that J/ψ suppression in nuclear collisions should provide an unambiguous signature of quark–gluon plasma formation.

Quarkonia are sensitive to the formation of a QGP via color screening

A thermal medium, like the quark-gluon plasma, induces color screening: $m_D \sim gT$



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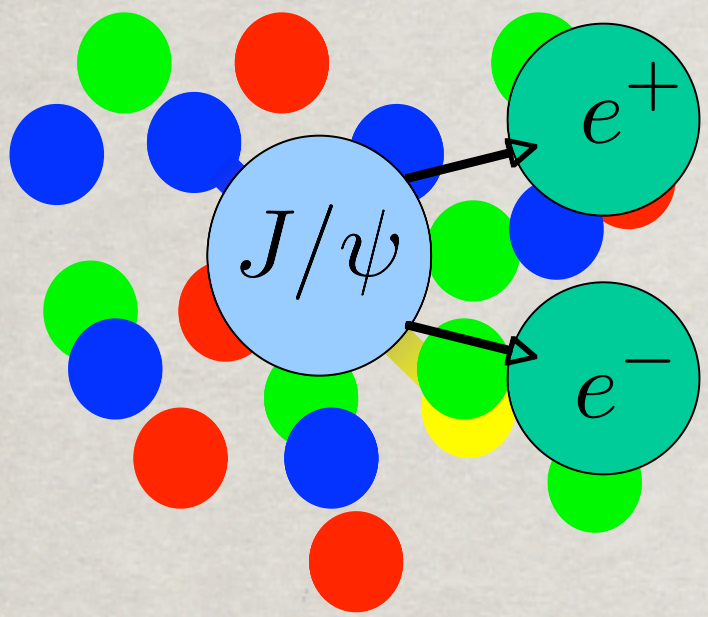

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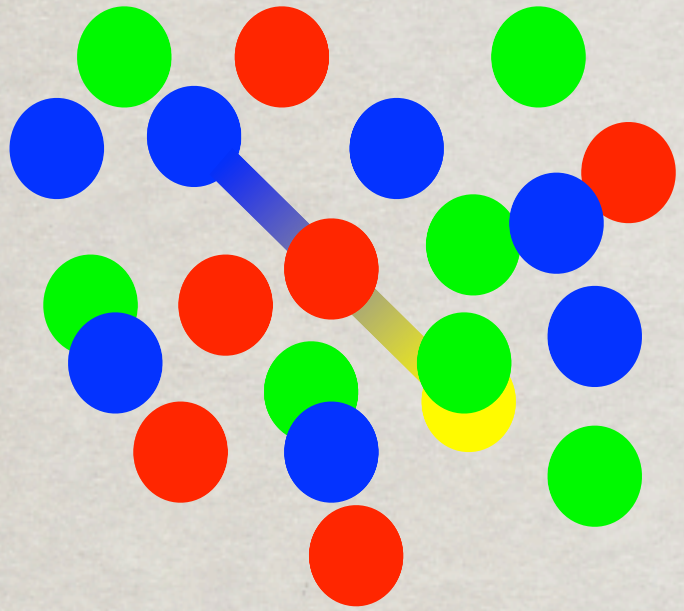

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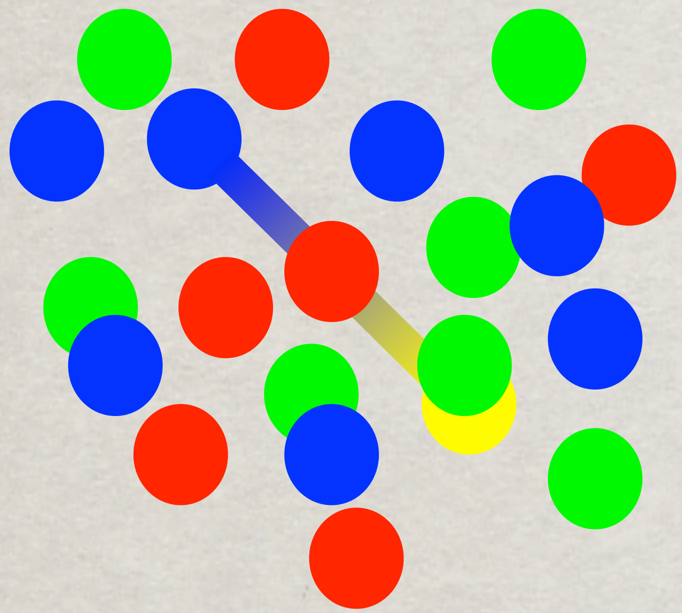

Debye charge screening

$$V(r) \sim -\alpha_s \frac{e^{-m_D r}}{r}$$

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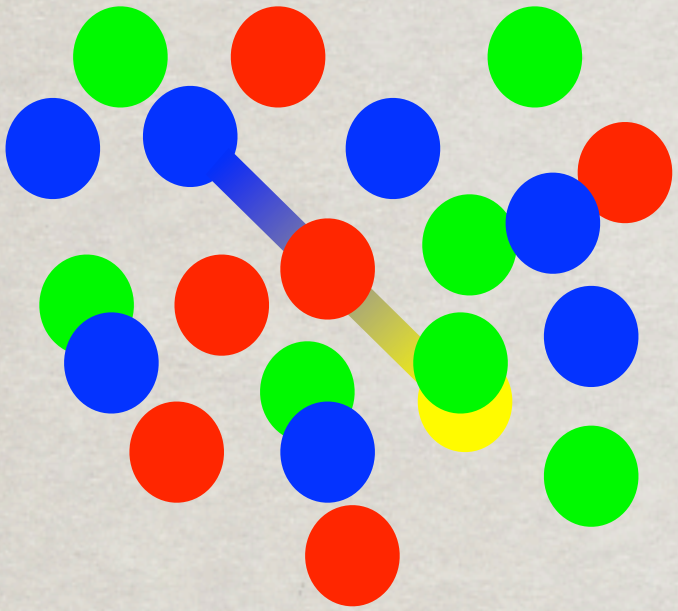

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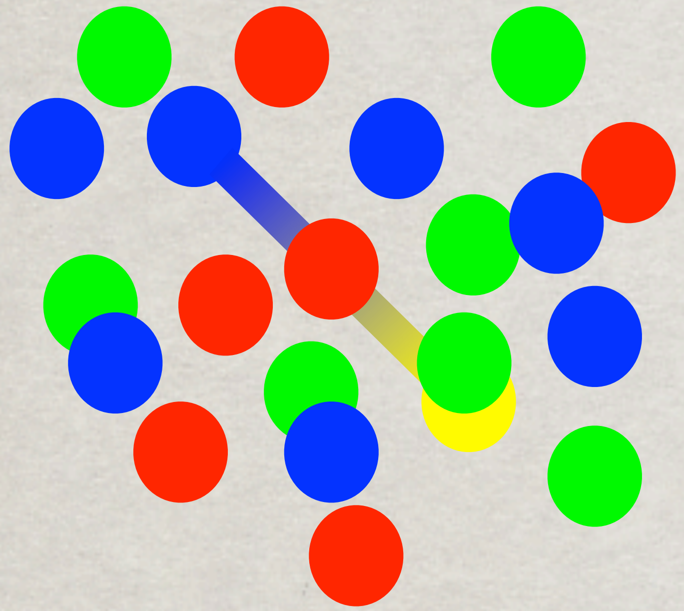

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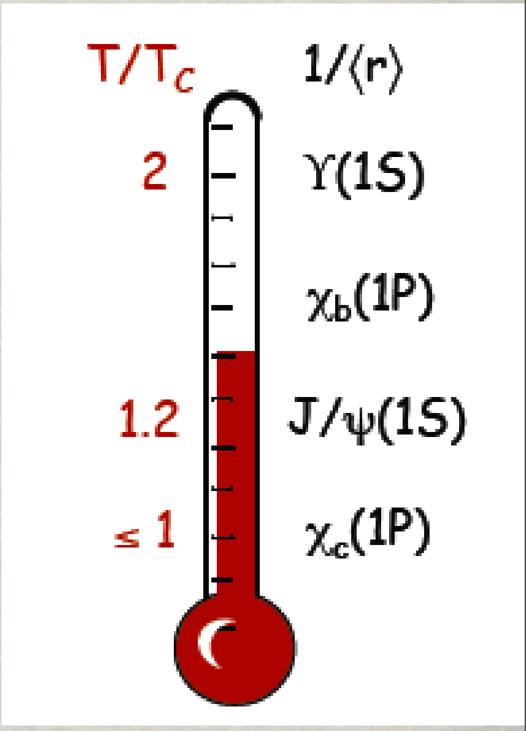

quarkonia dissociate at different temperature in dependence of their radius: they are a Quark Gluon Plasma thermometer

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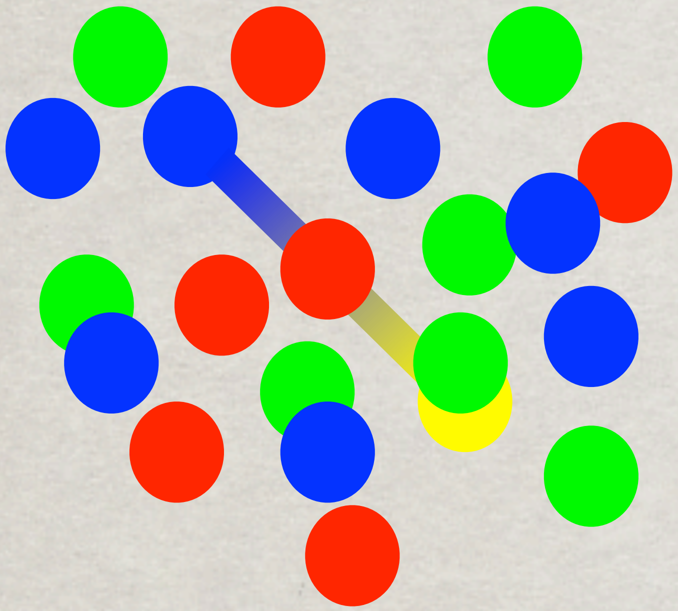

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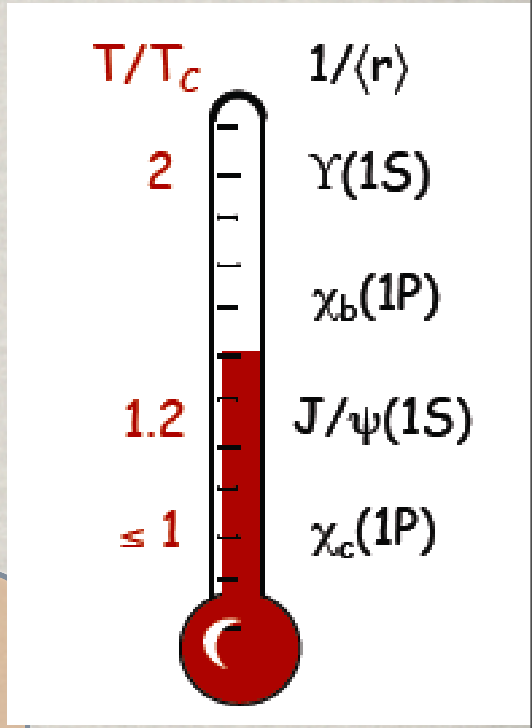

Physical Picture: color screening of the potential originates quarkonium dissociation when the radius is of the order of the inverse of the Debye screening

But, what is the quarkonium interaction potential in a hot medium?

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Potential models

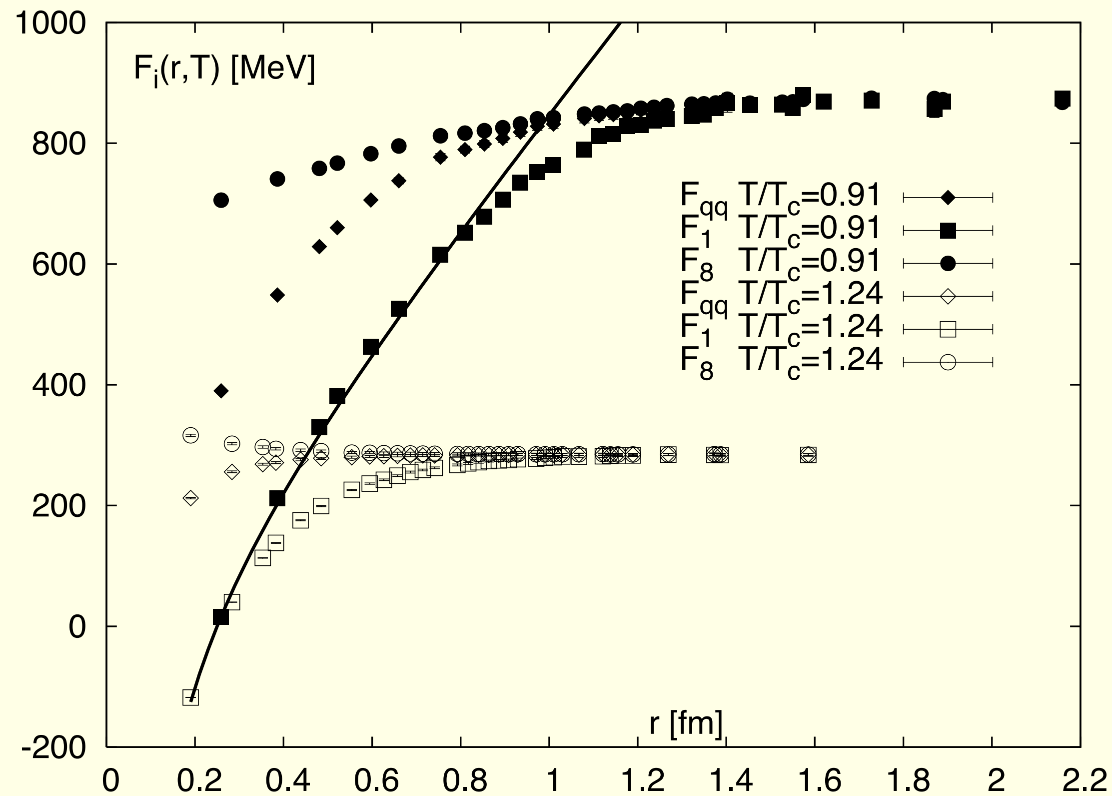
Digal, Petreczky, Satz 01
Wong 05-07
Mannarelli, Rapp 05
Mocsy, Petreczky 05-08
Alberico, Beraudo et al 05-08
Cabrera, Rapp 2007
Wong, Crater 07
Dumitru, Guo, Mocsy, Strickland 09
Rapp, Riek 10

- Either phenomenological potentials have been used so far or the free energy calculated on the lattice.

Singlet, octet and average free energy

- The free energy is not the static potential: the average free energy ($\sim \langle \mathrm{Tr}\, L^\dagger(r) \mathrm{Tr}\, L(0) \rangle$) is an overlap of singlet and octet quark-antiquark states, what is called the singlet ($\sim \langle \mathrm{Tr}\, L^\dagger(r)\, L(0) \rangle$) and the octet ($\sim \langle \mathrm{Tr}\, L^\dagger(r) \mathrm{Tr}\, L(0) \rangle$ $-1/3\, \langle \mathrm{Tr}\, L^\dagger(r)\, L(0) \rangle$) free energy are gauge dependent;

Owe Philipsen 08



2 flavor QCD ○ Kaczmarek Zantow PRD 71 (2005) 114510

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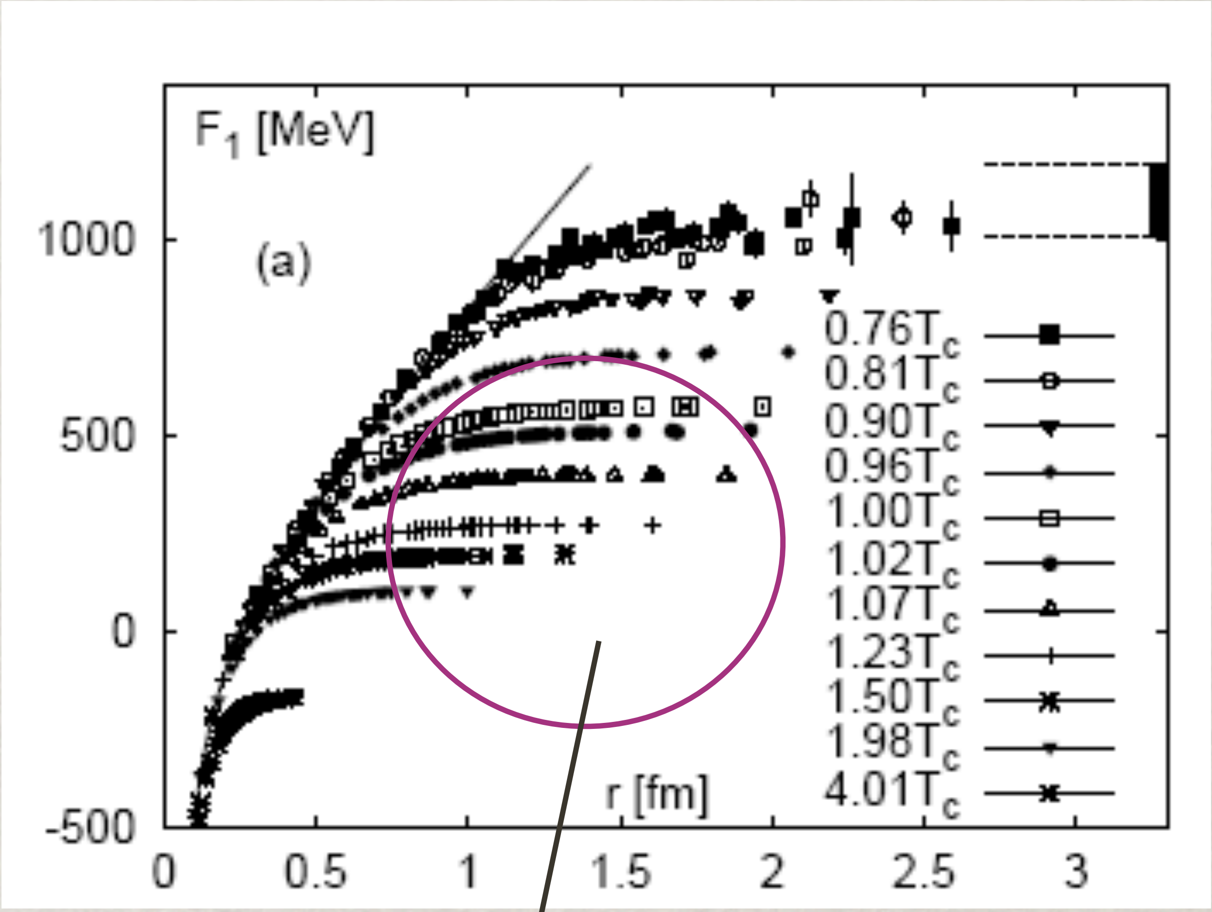
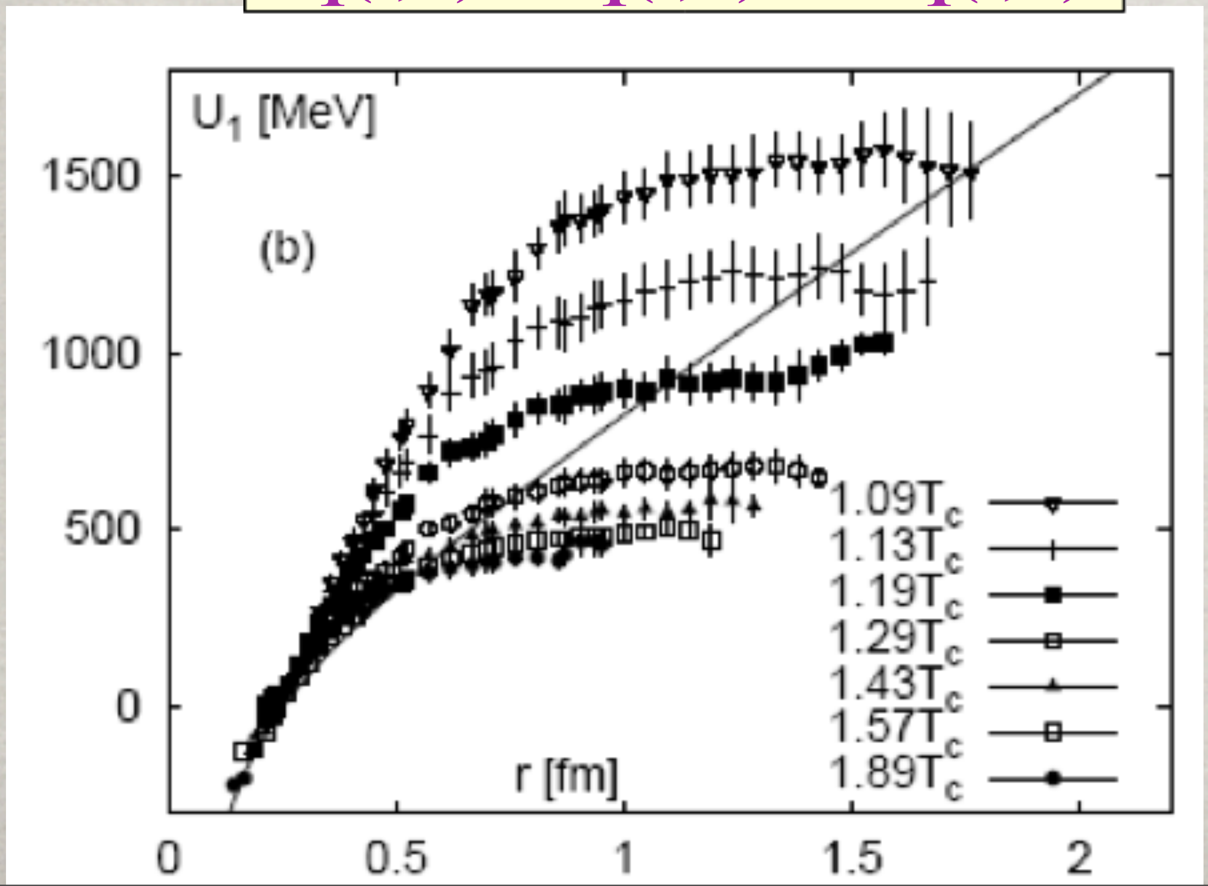
Potential models

Singlet free energy



$F_1(r,T) = U_1(r,T) - T\, S_1(r,T)$



Internal energy

flattening is due to screening

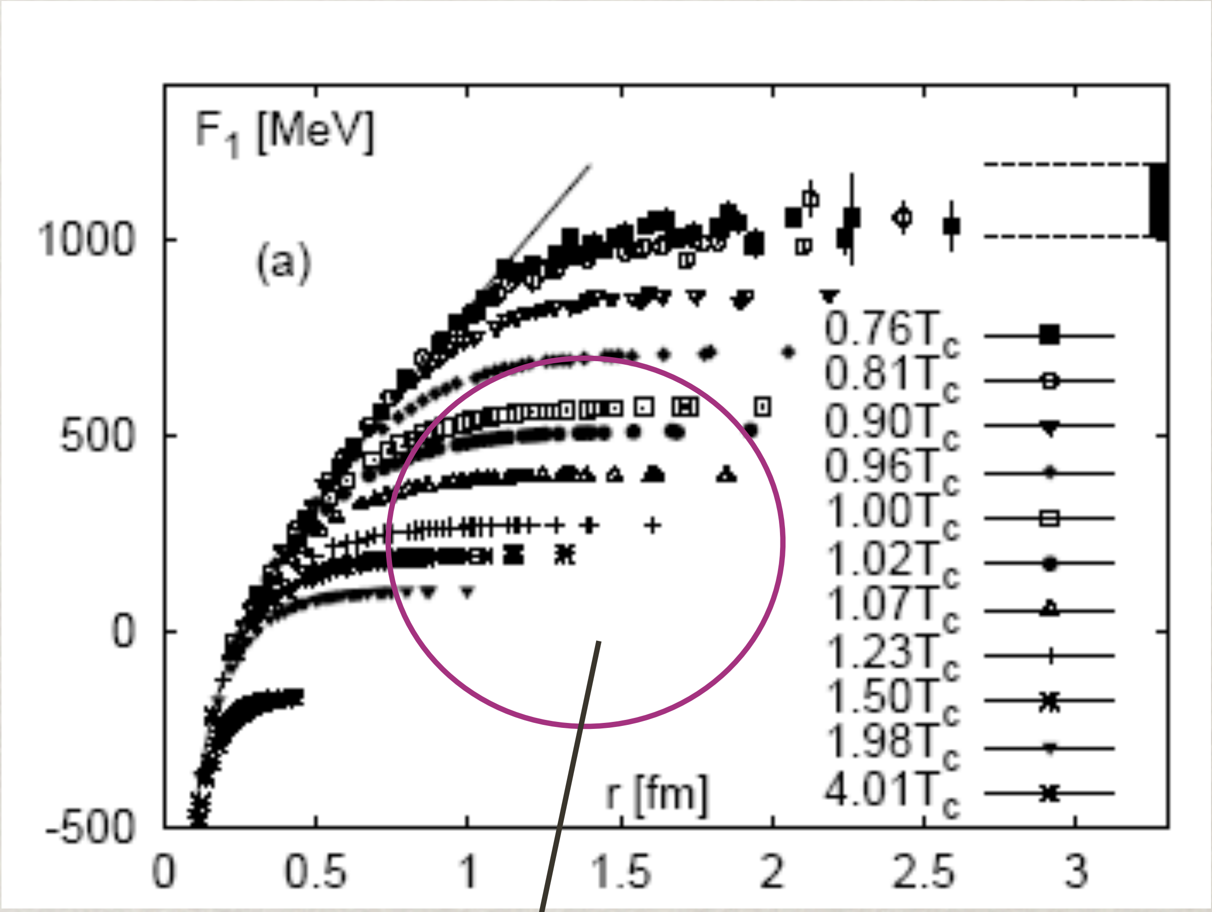
Kaczmarek Zantow'05
2 flavor QCD

But, what is the quarkonium interaction potential in a hot medium?

Potential models

Which of these is the QCD potential?
Are all effects incorporated?

Singlet free energy



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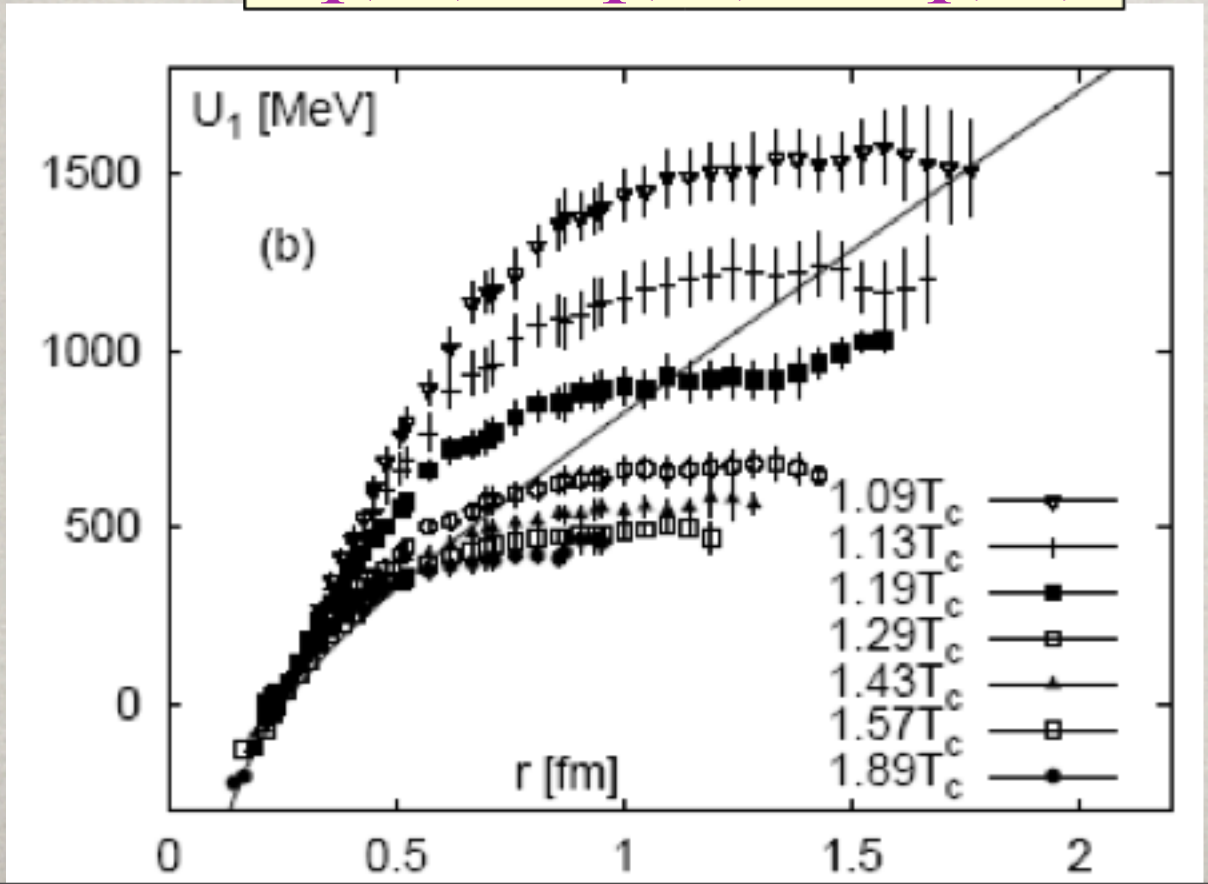

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The quarkonium potential at finite T

In order to study quarkonium properties in a thermal bath at temperature T, the quantity to be determined is the quarkonium potential, which describes the real-time evolution of a $Q\bar{Q}$ pair through the Schrödinger equation

$$E\,\Phi = \left(\frac{p^2}{m} + V(r,T)\right)\,\Phi$$

- In the full theory, $V(r,T)$ must come from a systematic expansion
  - in $1/m$ (non-relativistic expansion), the leading term being the static potential;
  - in the energy E (ultrasoft expansion).

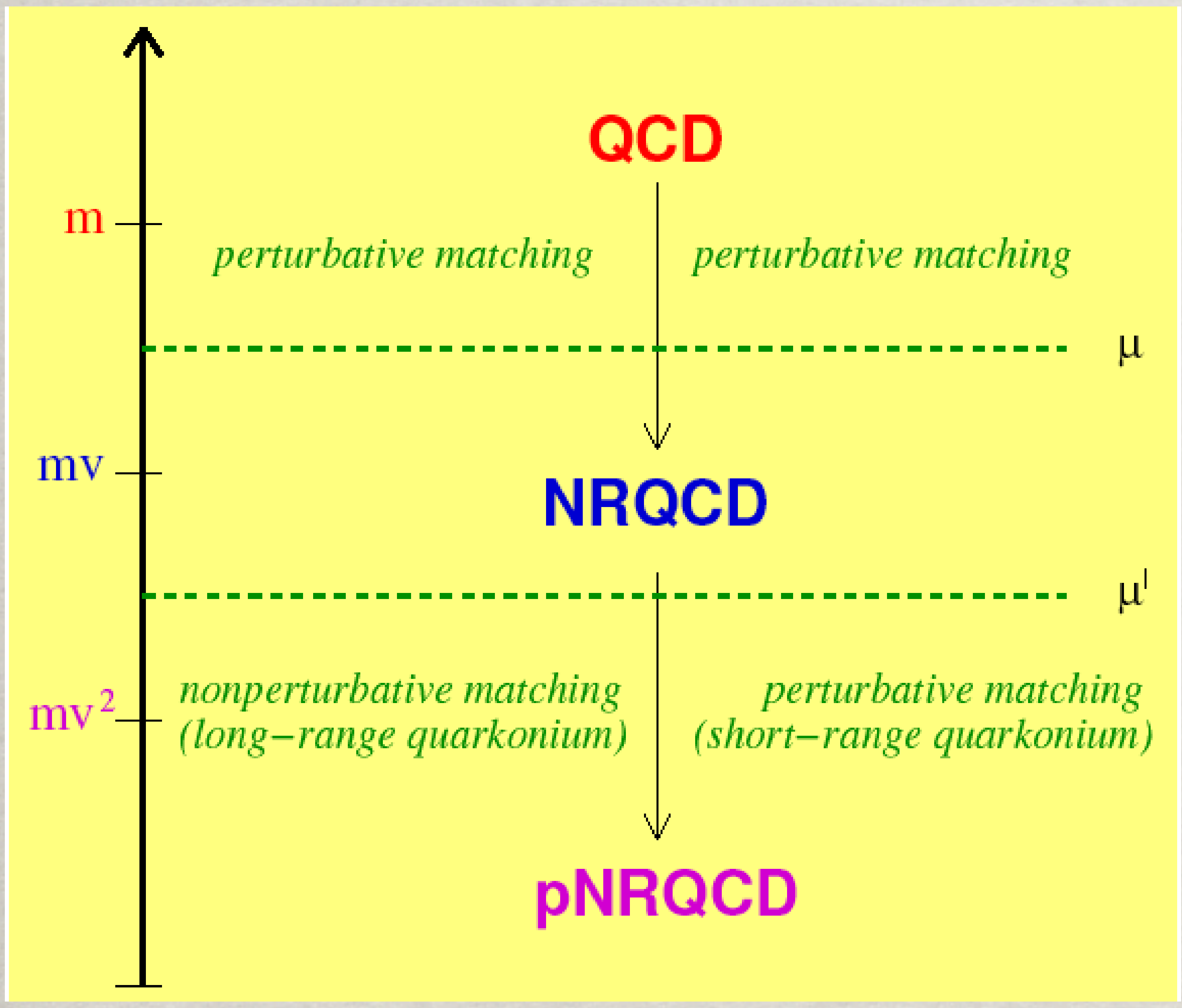
- One may exploit these expansions by constructing a suitable hierarchy of EFTs.

- The potential $V(r,T)$ encodes all contributions from scales larger than E and smaller than m. It will depend on the temperature if $m > T > E$; it will not depend on the temperature if $T < E$.

- Effects due to scales $\lesssim E$, which are sub-dominant, are not included in the potential, but they affect physical observables. They may be systematically included in the EFT by introducing other low-energy degrees of freedom besides Φ.

Quarkonium at T=0 with effective field theories

Color degrees of freedom
3X3=1+8
singlet and octet QQbar



Hard

Soft
(relative
momentum)

Ultrasoft
(binding energy)

In QCD another scale is relevant Λ_{QCD}

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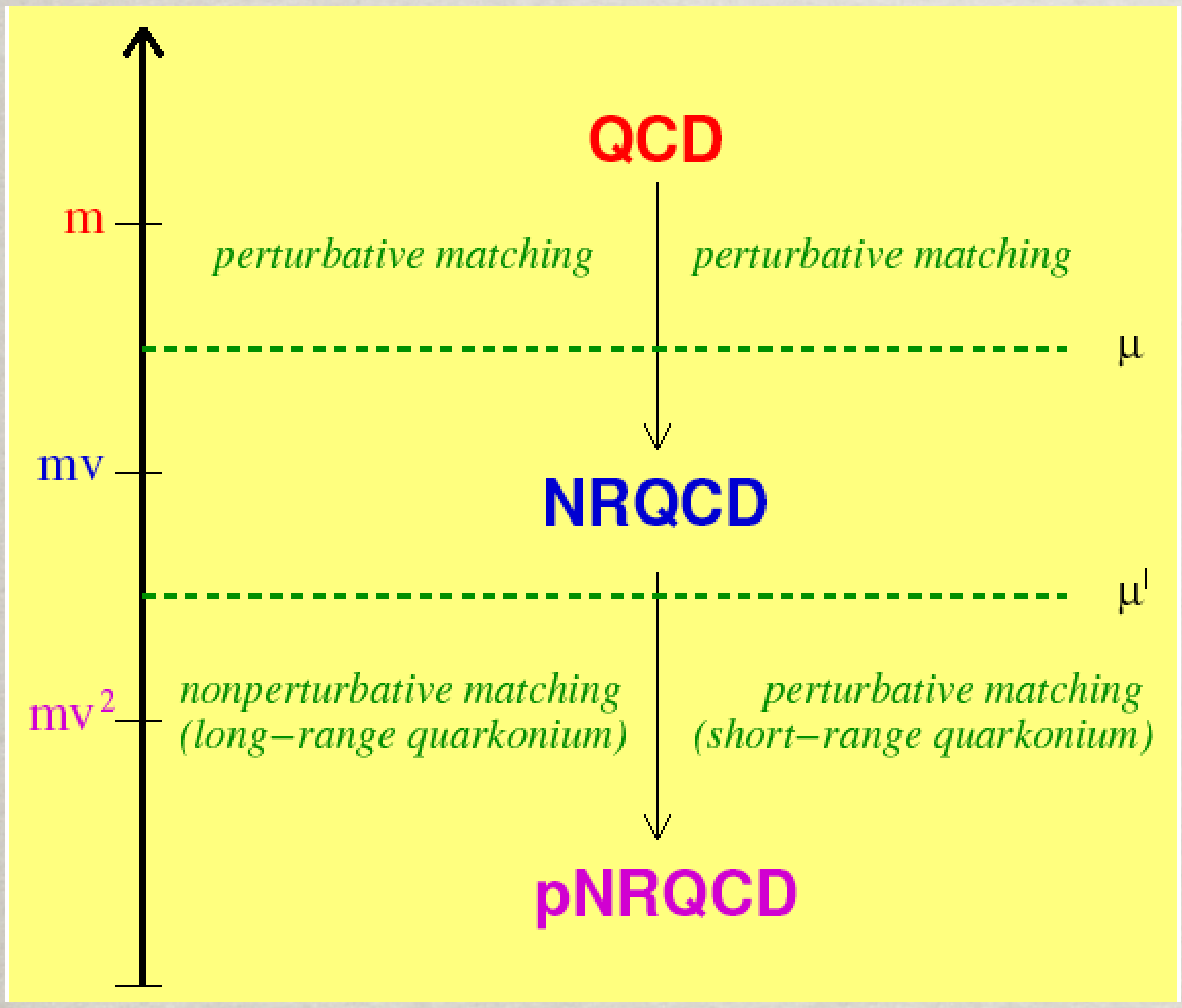

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$$\mathcal{L}_{\rm EFT} = \sum_n c_n(E_\Lambda/\mu)\frac{O_n(\mu,\lambda)}{E_\Lambda}$$

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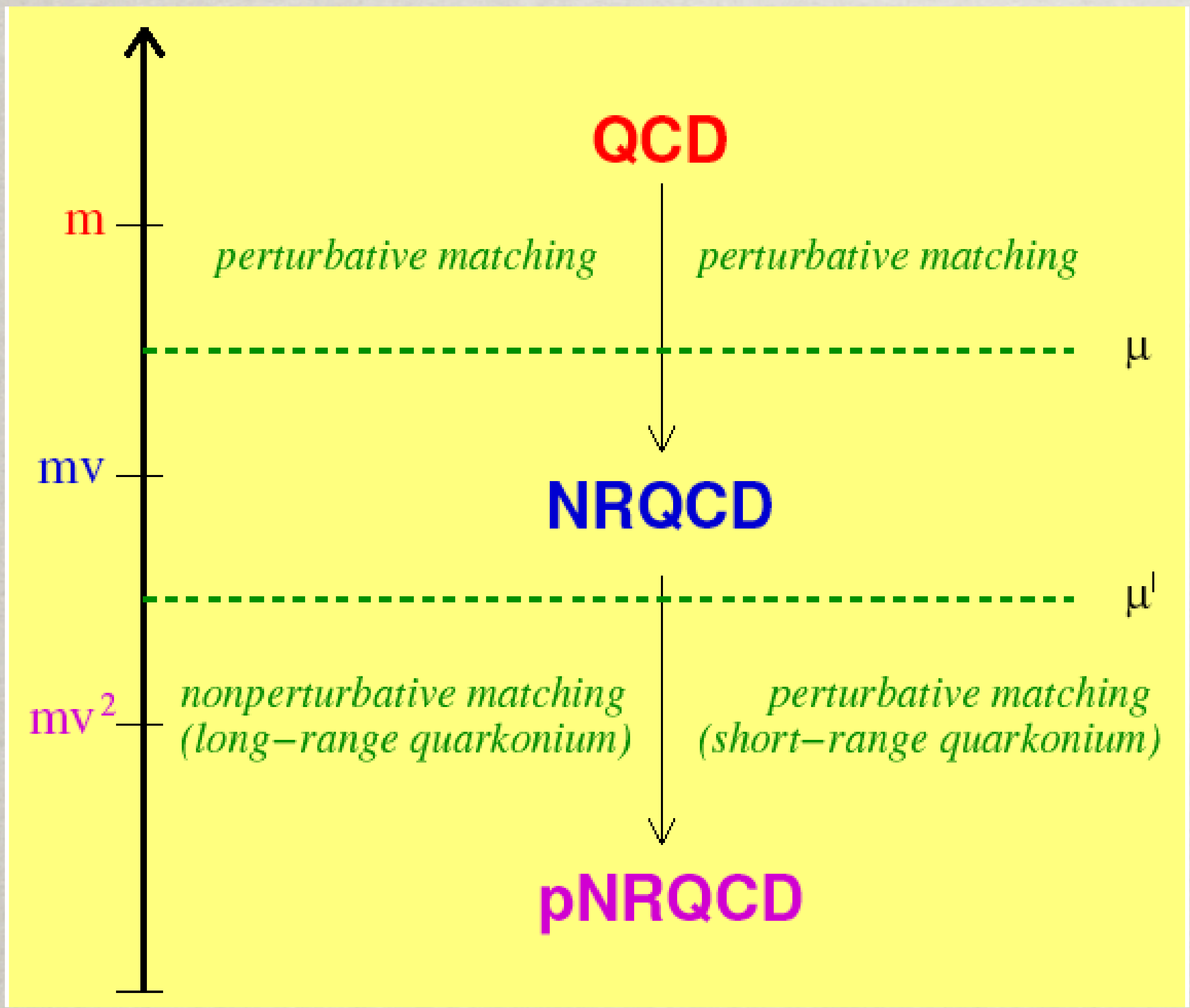

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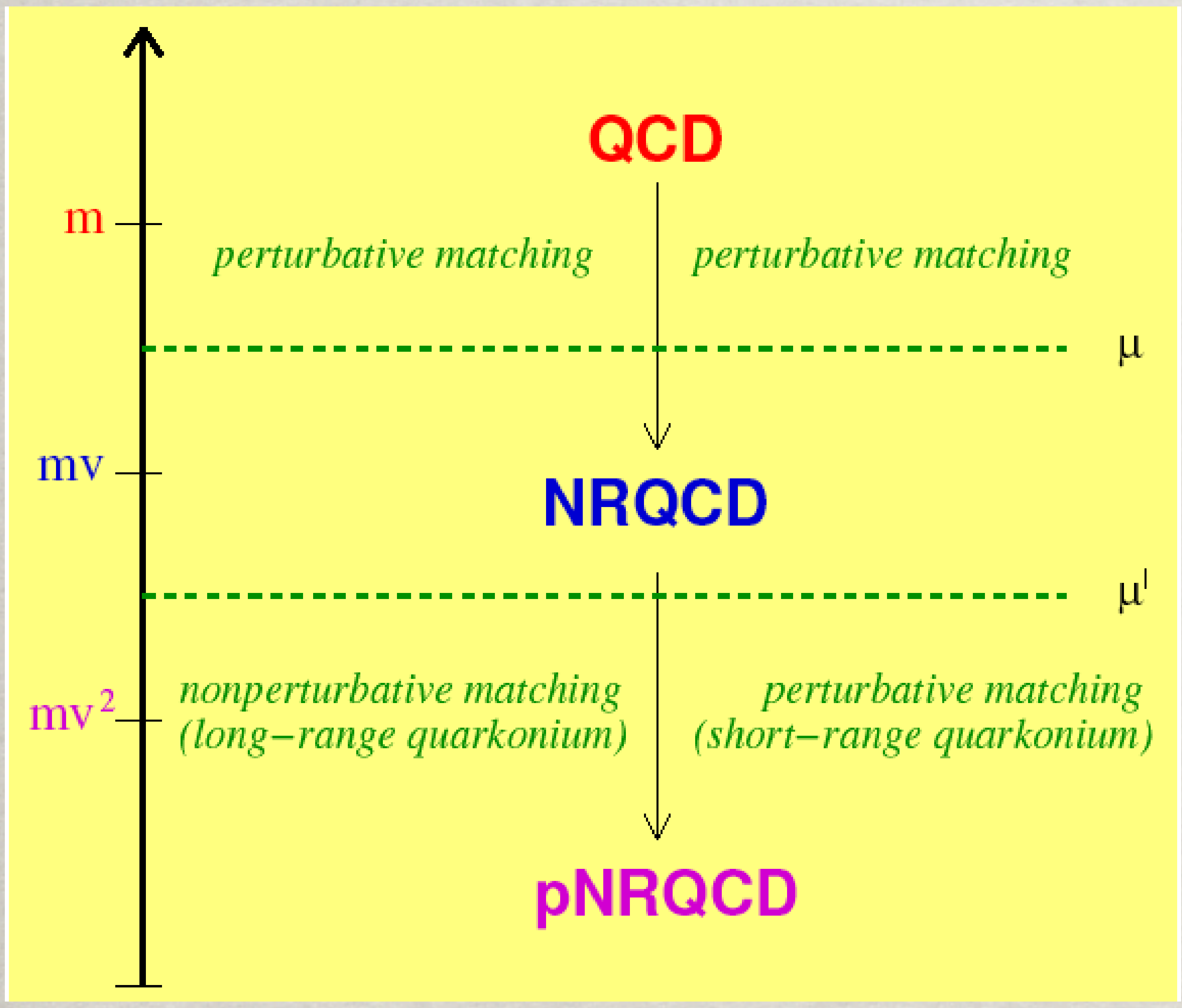

Hard

$$\frac{E_\lambda}{E_\Lambda} = \frac{mv}{m}$$

Soft (relative momentum)

Ultrasoft (binding energy)

$$\mathcal{L}_{\mathrm{EFT}} = \sum_n c_n(E_\Lambda/\mu)\frac{O_n(\mu,\lambda)}{E_\Lambda} \qquad \langle O_n \rangle \sim E_\lambda^n$$

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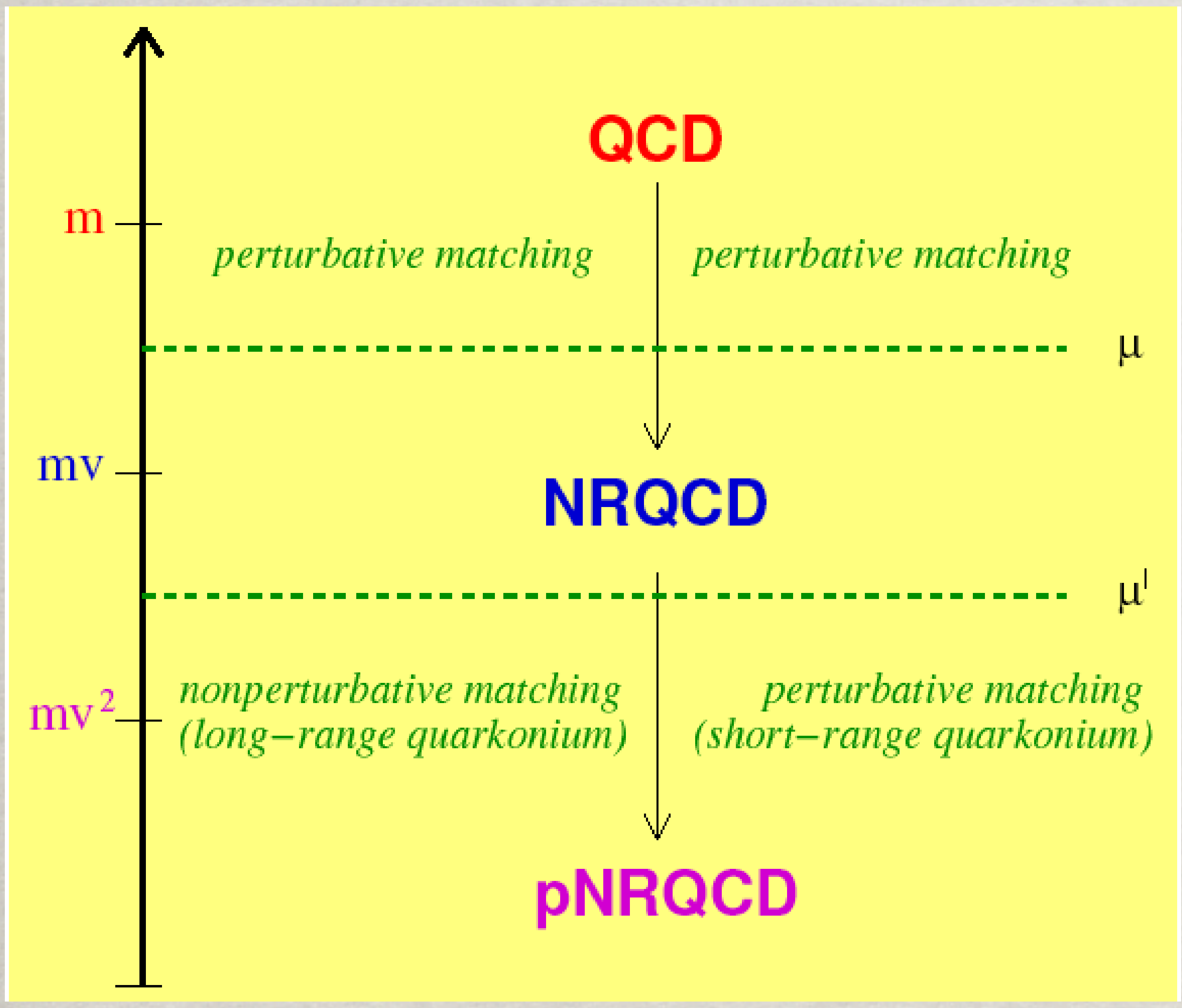

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$$\frac{E_\lambda}{E_\Lambda} = \frac{mv}{m}$$

Soft (relative momentum)

$$\frac{E_\lambda}{E_\Lambda} = \frac{mv^2}{mv}$$

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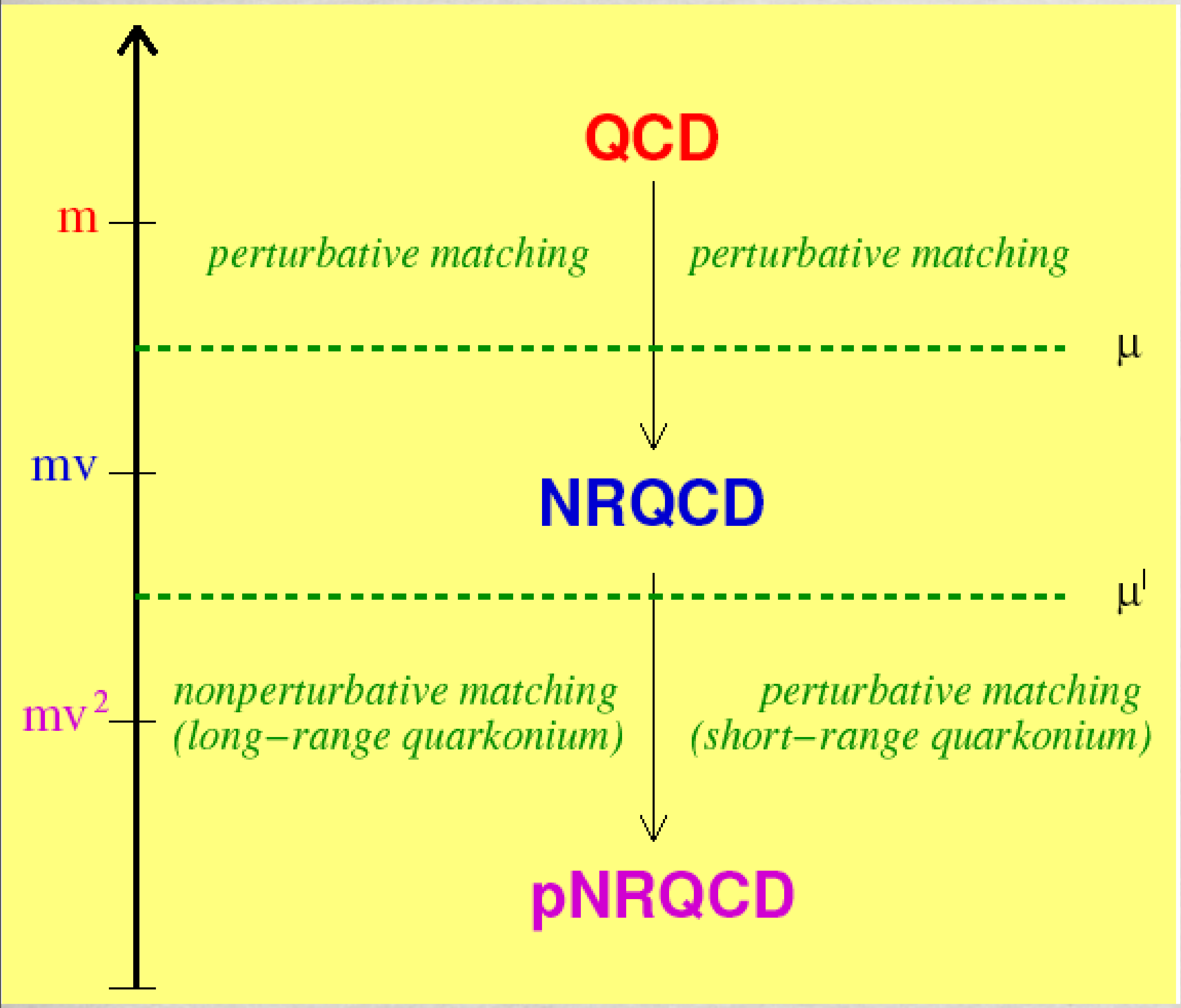
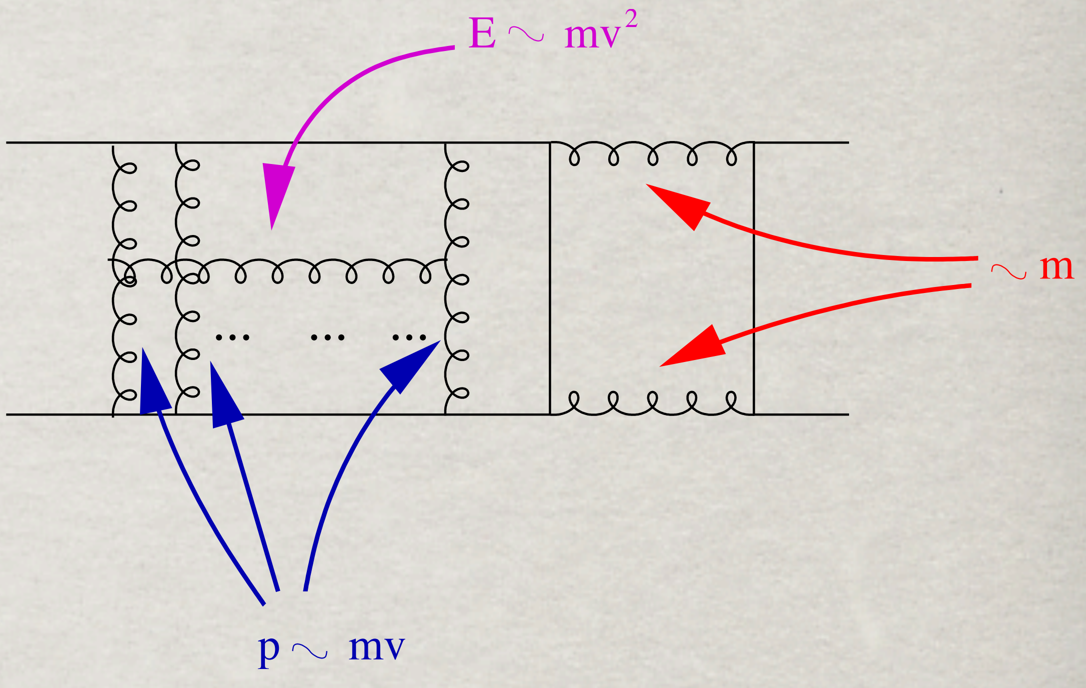
Quarkonium at T=0: Non Relativistic QCD (NRQCD)





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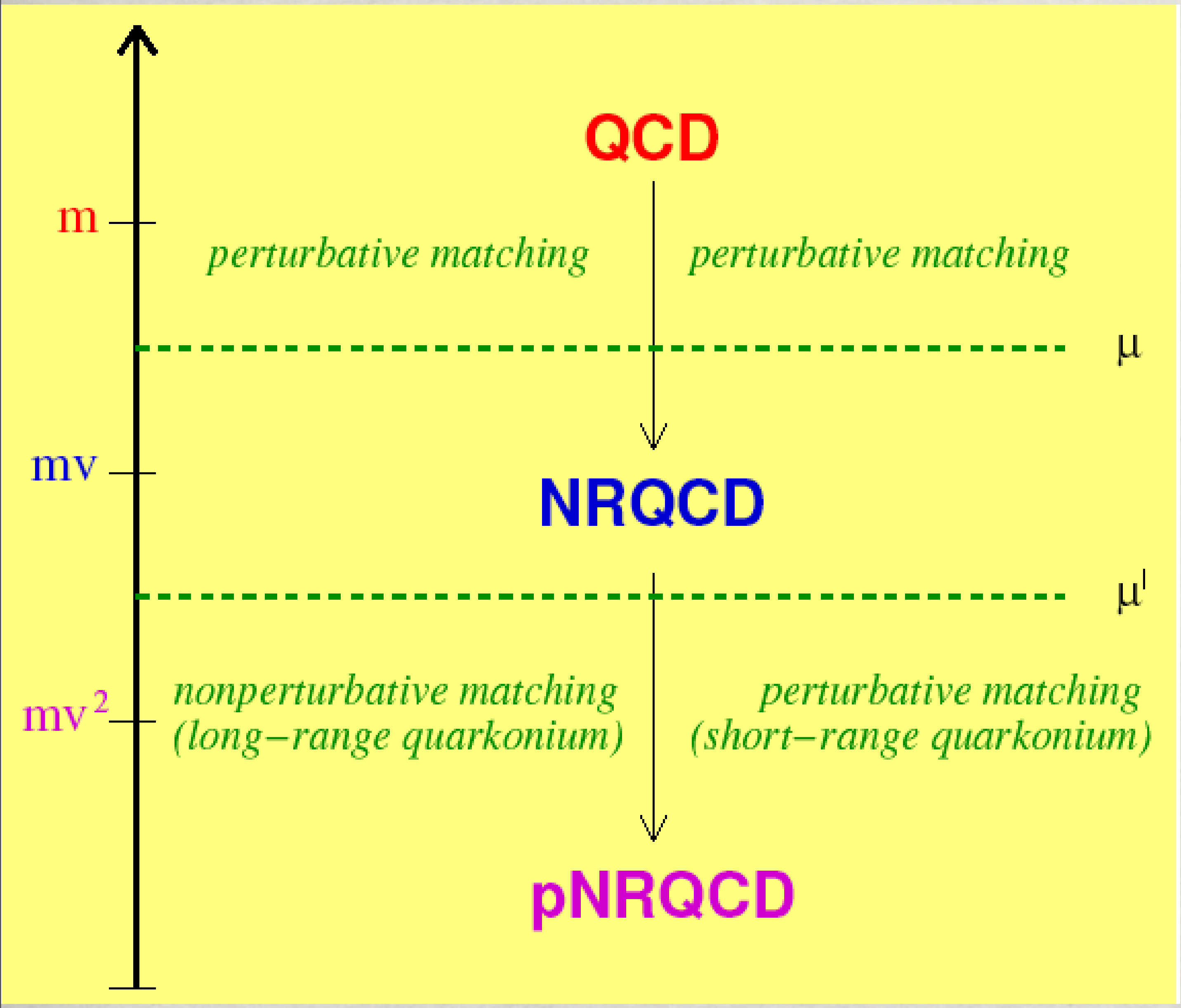

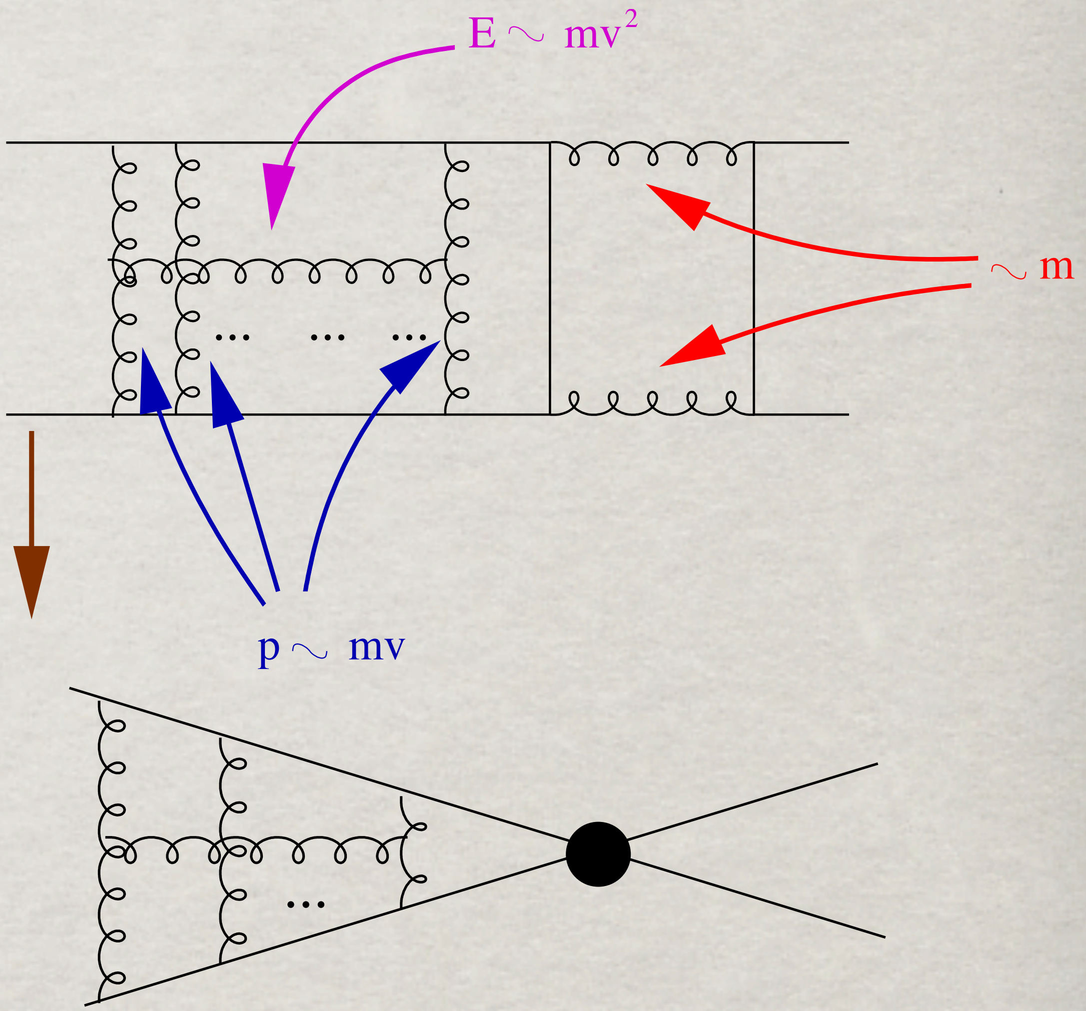

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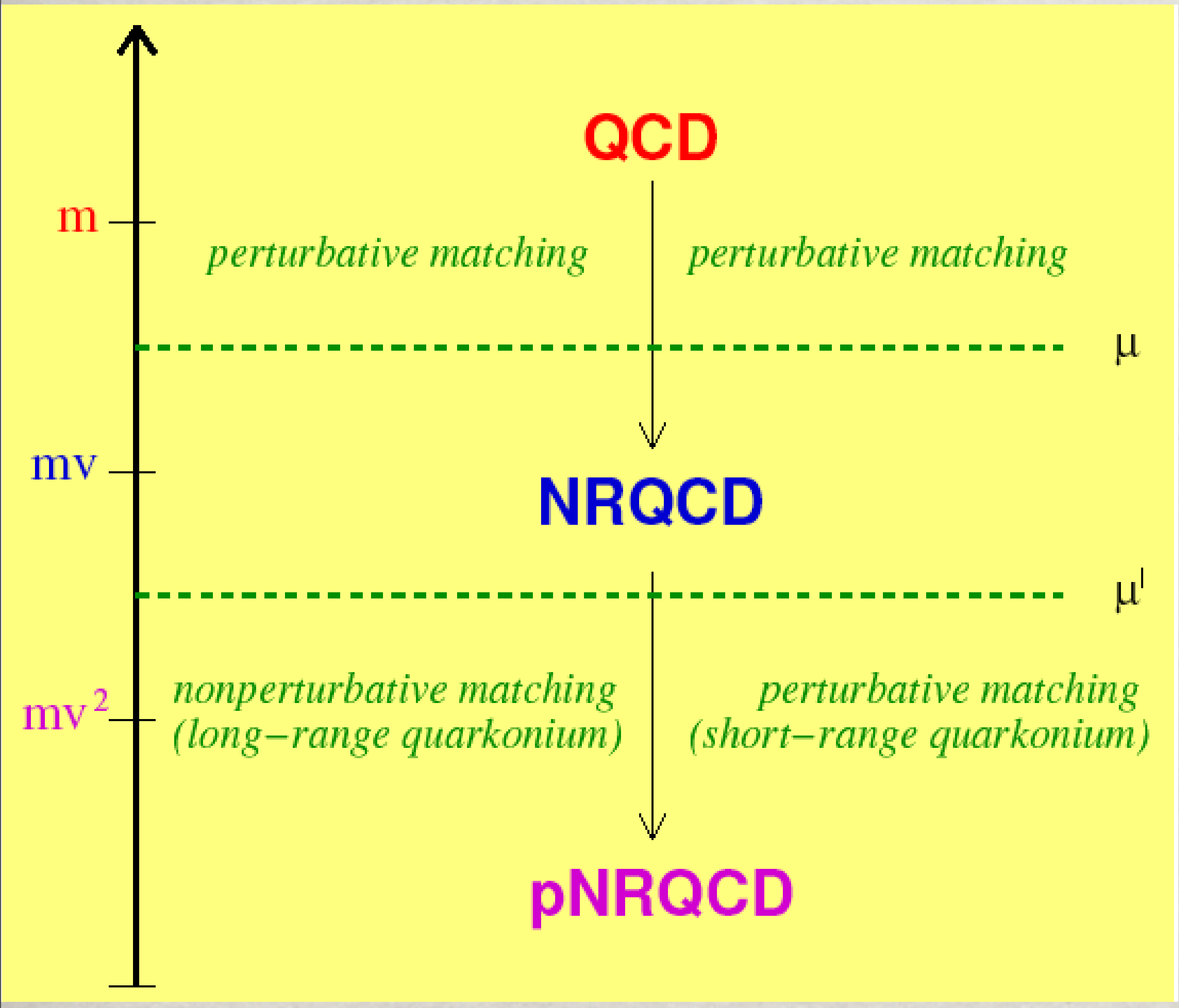
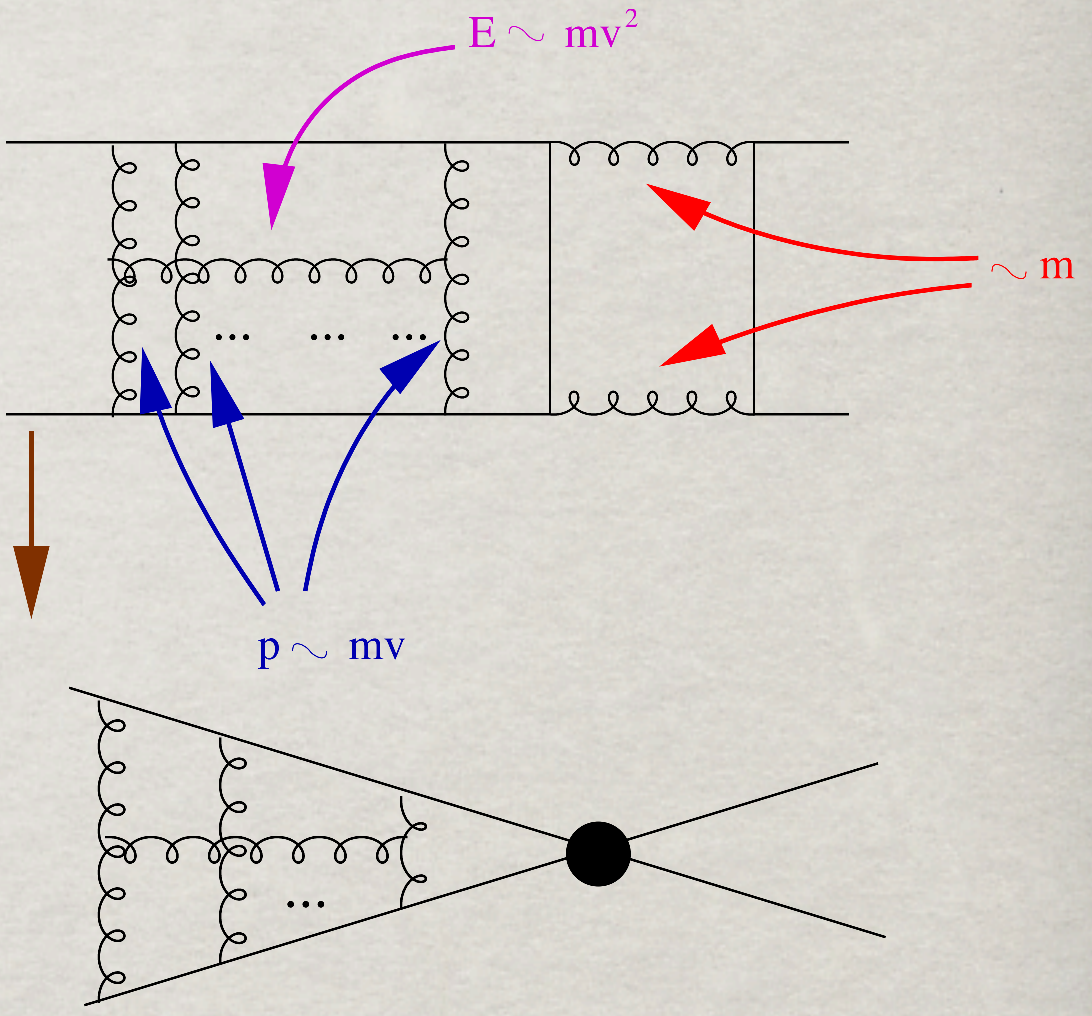
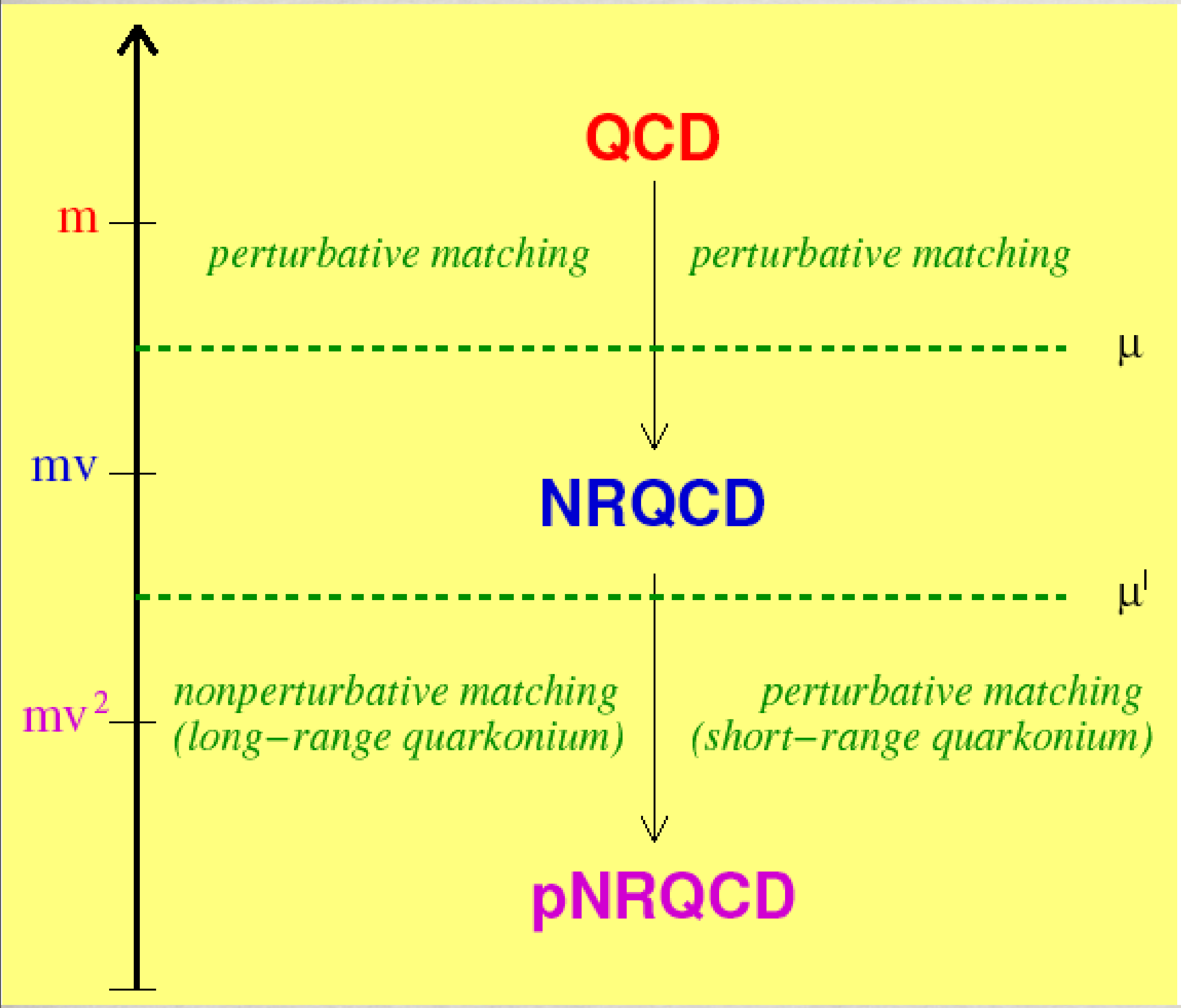
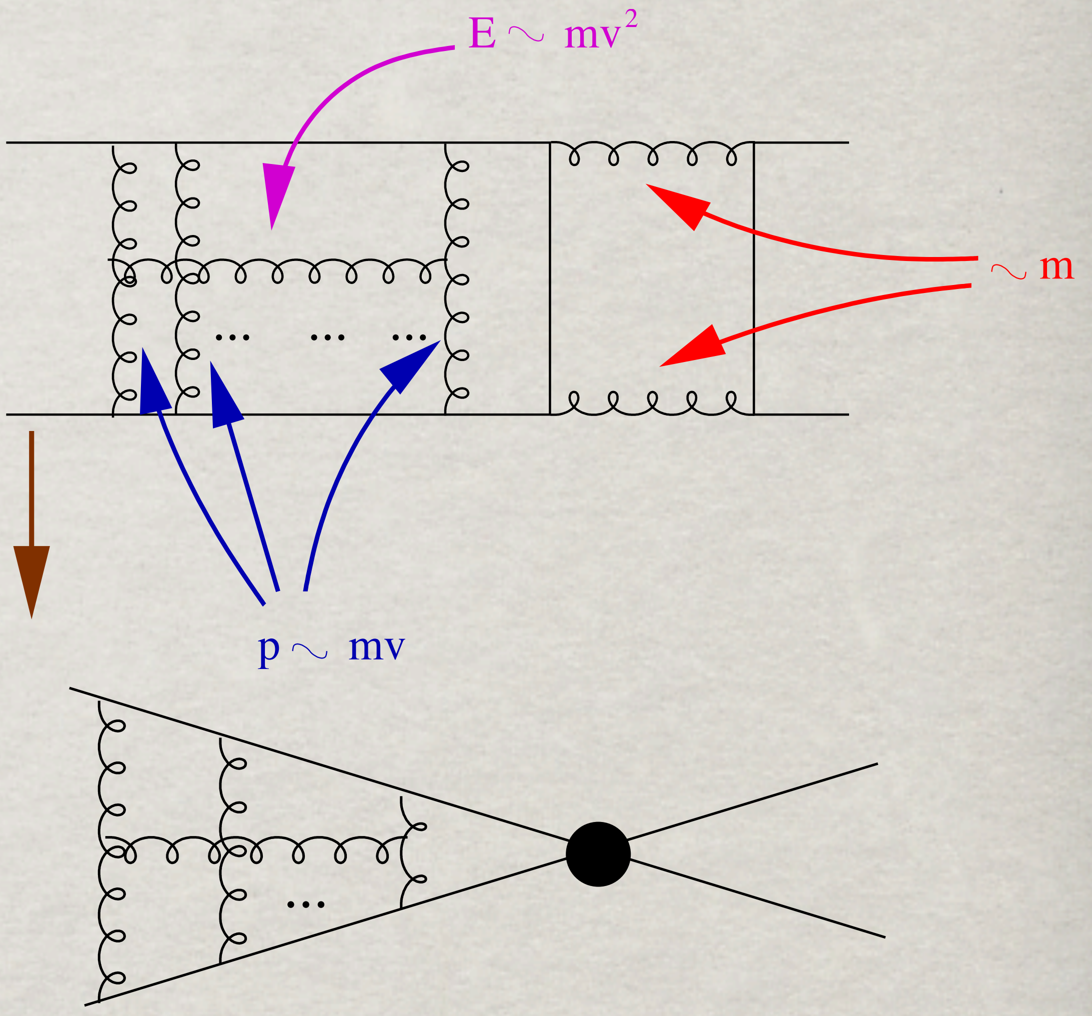




$$\mathcal{L}_{\mathrm{NRQCD}} = \sum_n c(\alpha_{\mathrm{s}}(m/\mu)) \times \frac{O_n(\mu, \lambda)}{m^n}$$

Quarkonium at T=0: potentialNonRelativistic QCD (pNRQCD)





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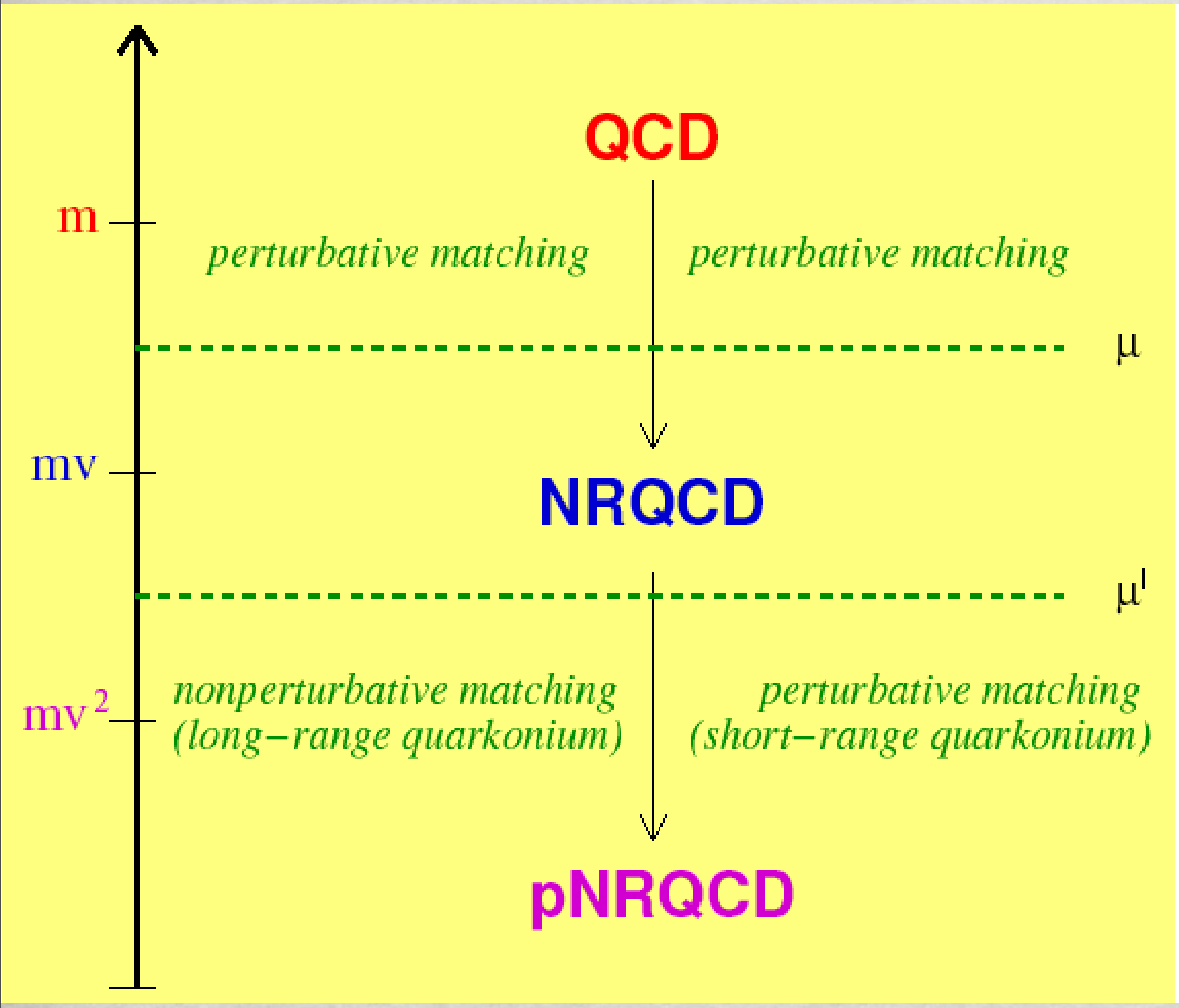

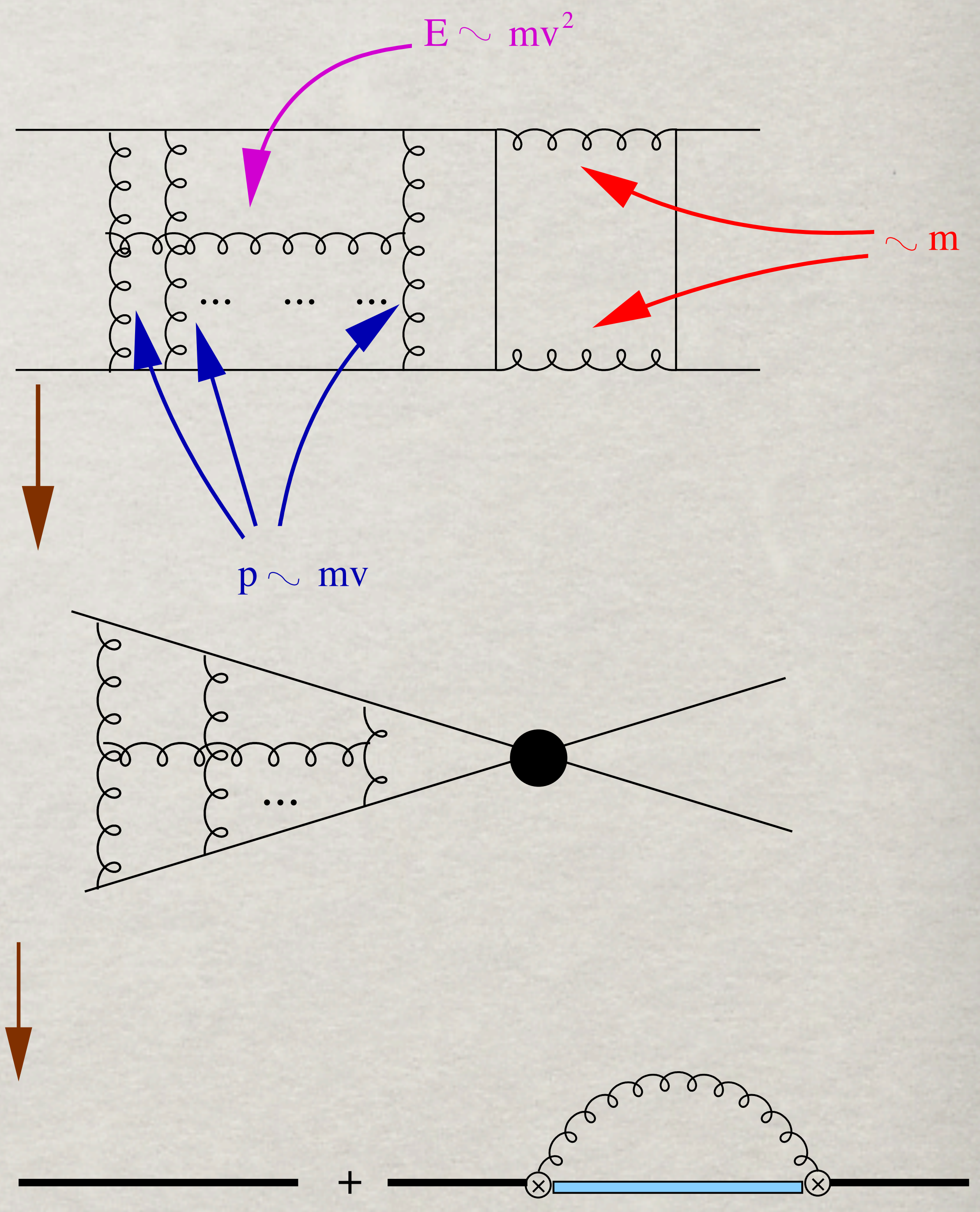

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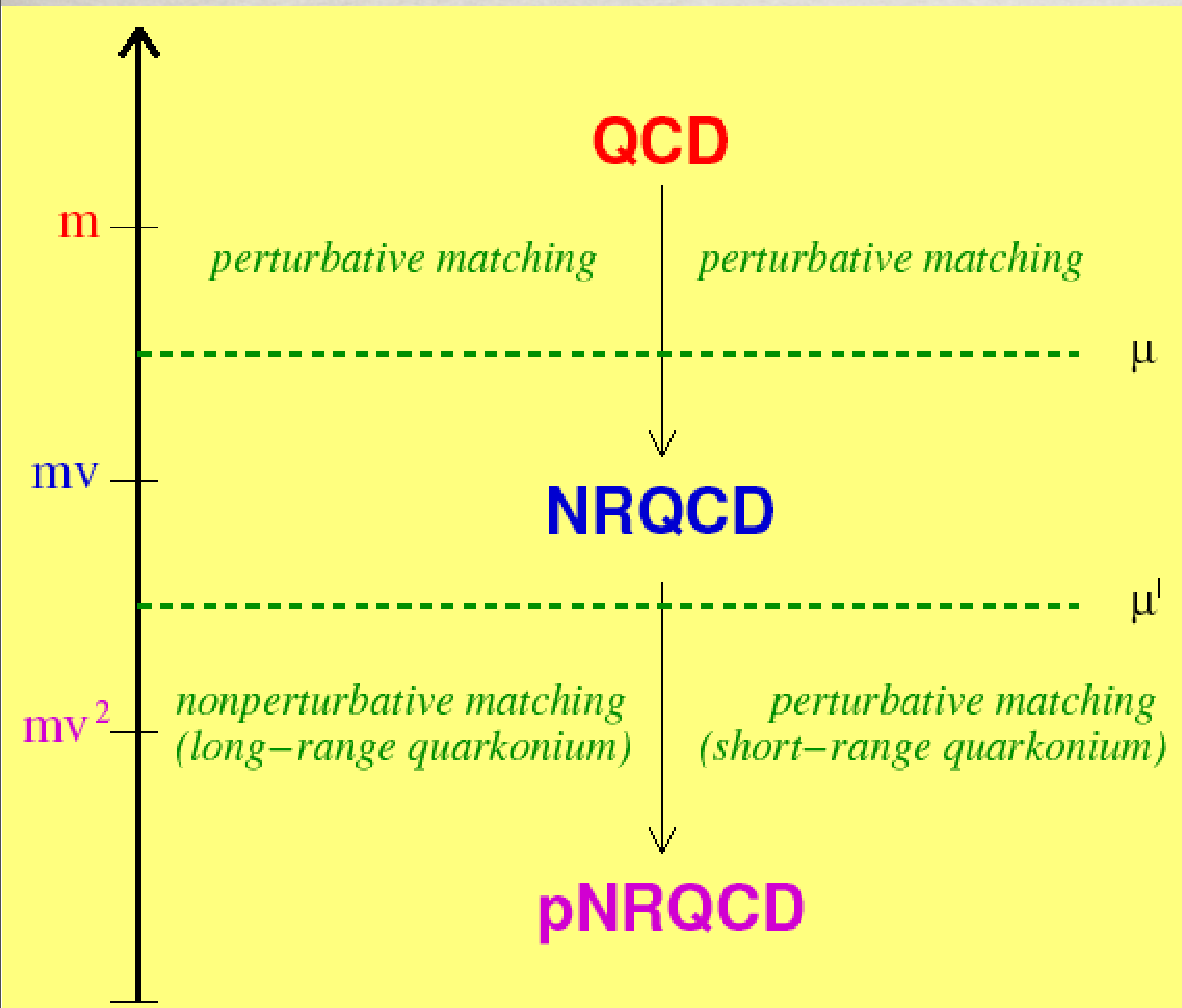

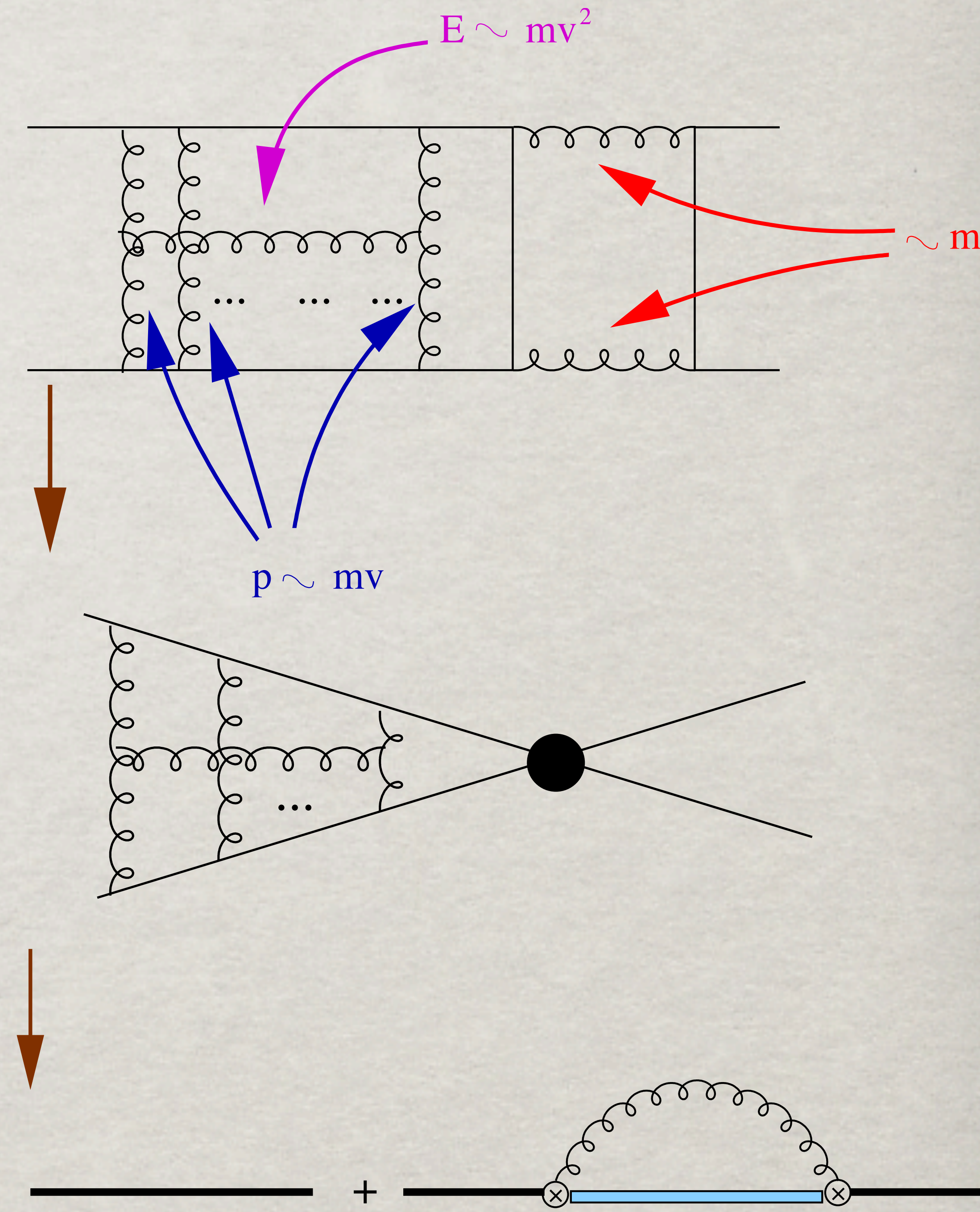

$$\mathcal{L}_{\rm pNRQCD} = \sum_k \sum_n \frac{1}{m^k} c_k(\alpha_{\rm s}(m/\mu)) \times V(r\mu', r\mu) \times O_n(\mu', \lambda)\, r^n$$

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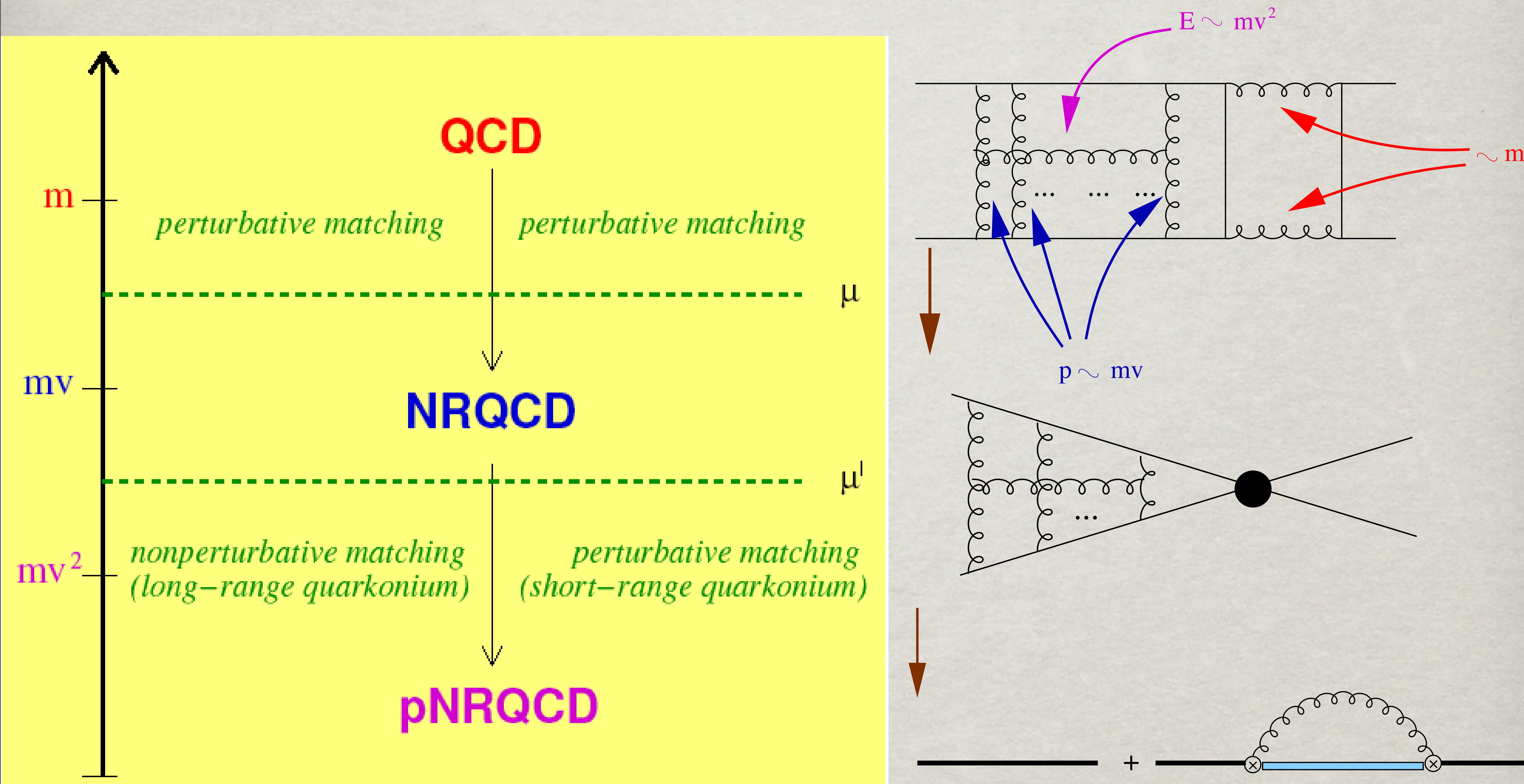

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Quarkonium at finite temperature

Quarkonium in a medium is characterized by different energy and momentum scales:

- the scales of a non-relativistic bound state (v is the relative heavy-quark velocity):
  - m (mass),
  - mv (momentum transfer, inverse distance),
  - mv^2 (kinetic energy, binding energy, potential V), ...

- the thermodynamical scales:
  - πT (temperature),
  - m_D (Debye mass, i.e. screening of the chromoelectric interactions), ...

and lower energy scales: magnetic screening, Λ_{QCD}

Non-relativistic scales are hierarchically ordered: $m \gg mv \gg mv^2$,
we may assume that also the thermodynamical scales are: $\pi T \gg m_D$.

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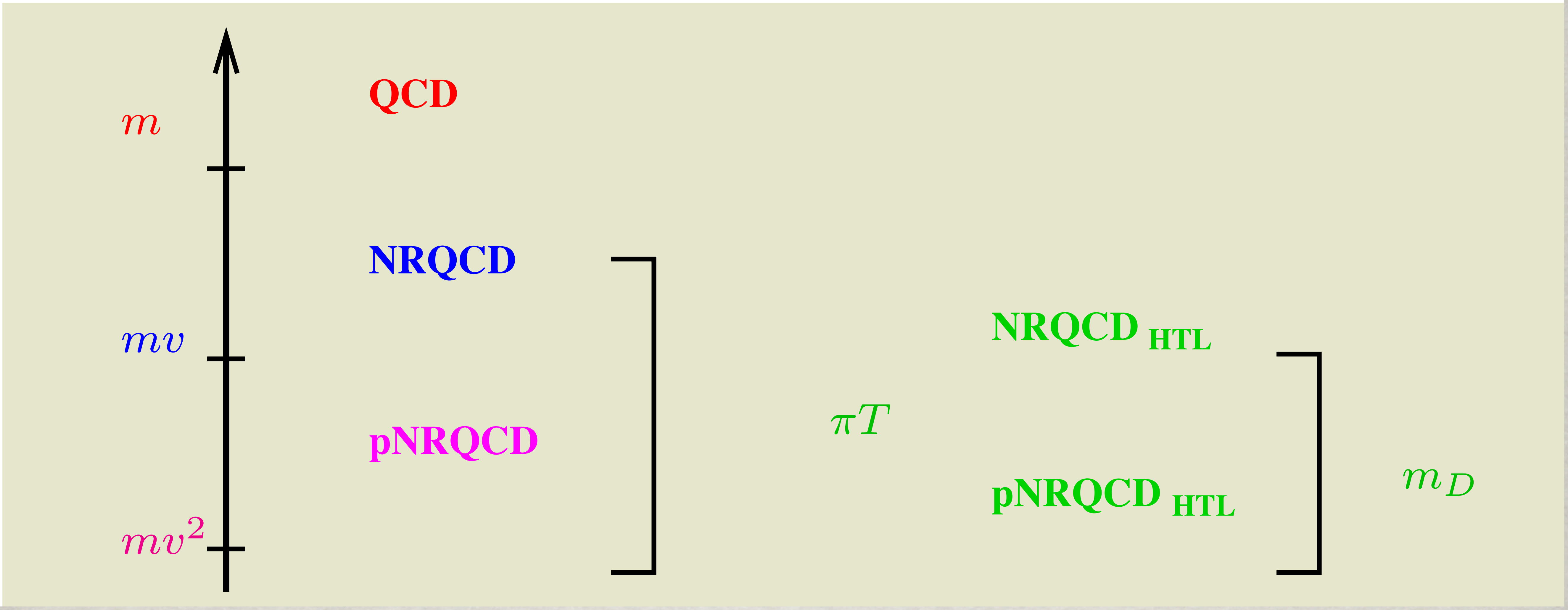
Without heavy quarks an EFT already exists that comes from integrating out hard gluon of p \sim T:
Hard Thermal Loop EFT

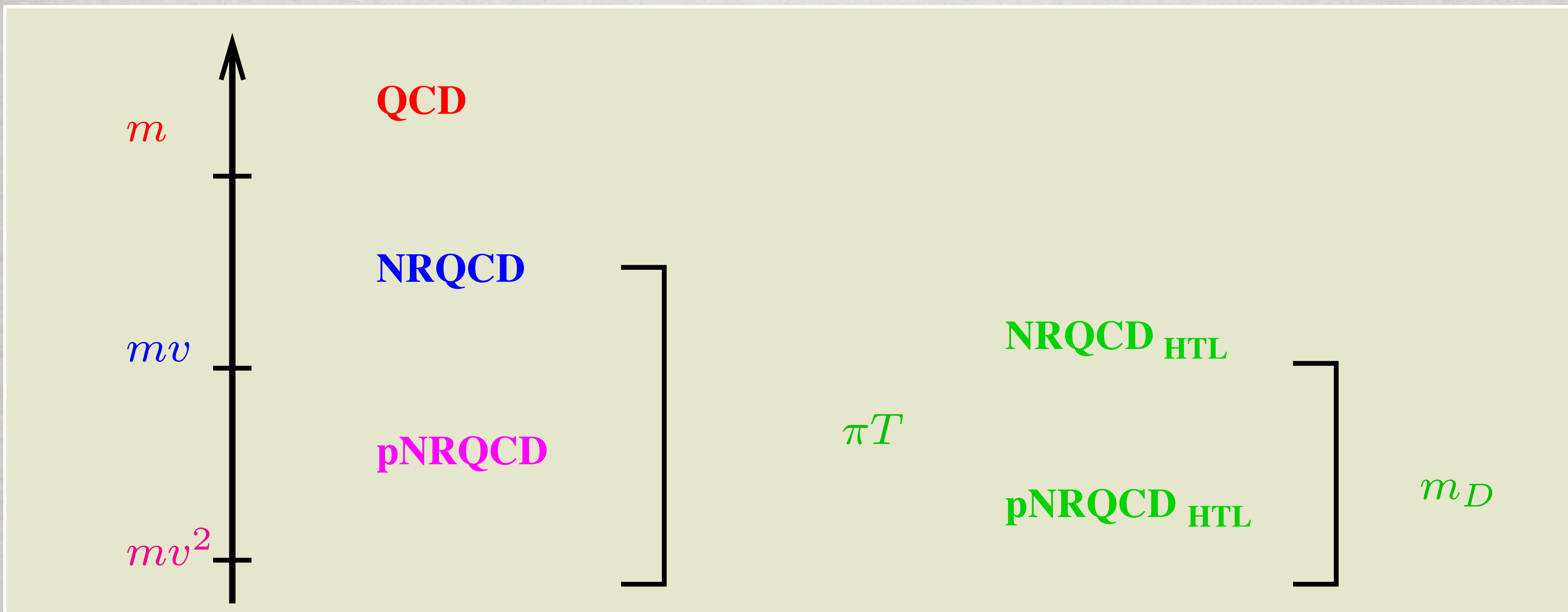
Braaten Pisarski 90

Quarkonium at finite T: EFT treatment



N.B., Ghiglieri, Petreczky, Vairo 08, (in QED Escobedo, Soto 08)

Quarkonium at finite T: EFT treatment



We work under the conditions:

We assume that bound states exist for

- $T \ll m$
- $\langle 1/r \rangle \sim mv \gtrsim m_D$

We neglect smaller thermodynamical scales.

In the weak coupling regime:

- $v \sim \alpha_{\rm s} \ll 1$; valid for tightly bound states: $\Upsilon(1S)$, J/ψ, ...
- $T \gg gT \sim m_D$.

Effects due to the scale $\Lambda_{\rm QCD}$ will not be considered.

N.B., Ghiglieri, Petreczky, Vairo 08, (in QED Escobedo, Soto 08)

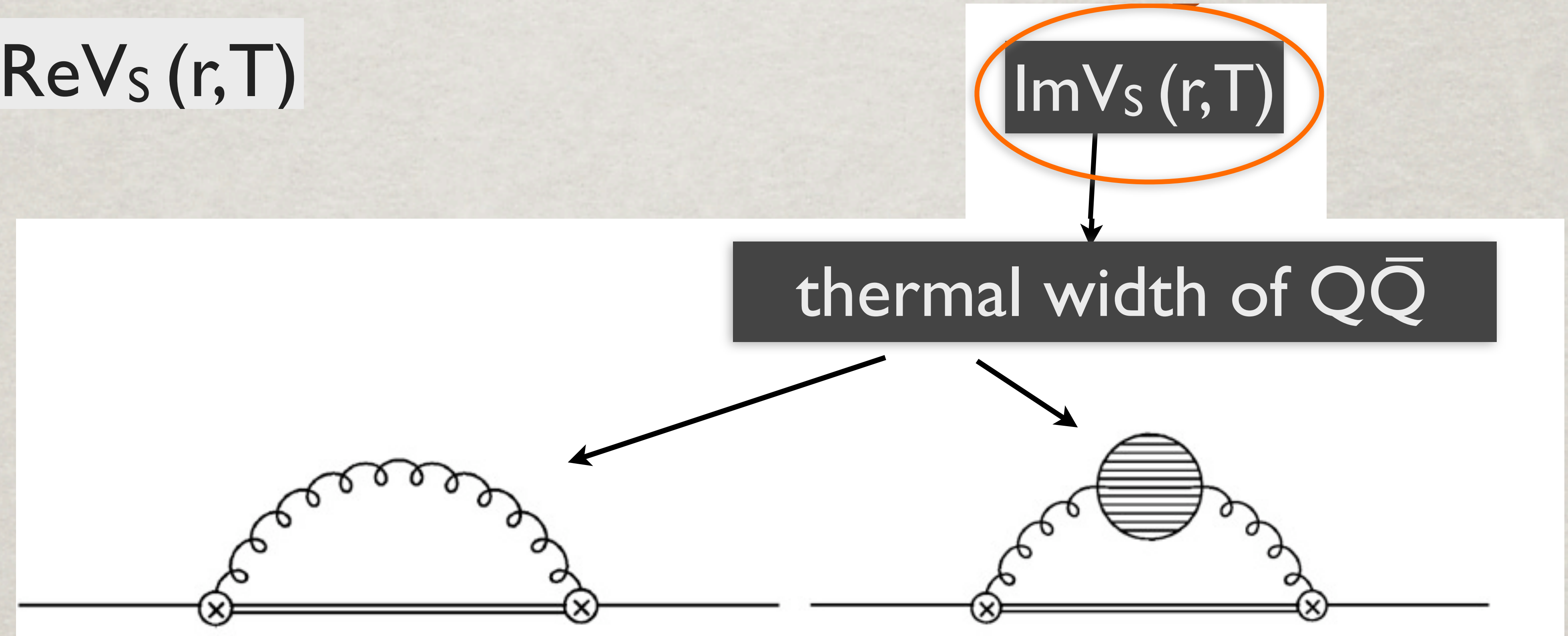
The singlet static potential and the static energy (pNRQCD)

We have calculated the potential for all the situations from T bigger than the inverse radius 1/r to smaller than the energy E in small coupling

N.B., Ghiglieri, Petreczky, Vairo

- The thermal part of the potential has a real and an imaginary part

$\mathrm{Re}V_S\,(r,T)$



Singlet-to-octet

New effect, specific of QCD

dominates for E/m_D>>1

(gluo dissociation)

Landau damping

Known from QED

dominates for m_D/E>>1

(quasi free dissociation)

N. B., Ghiglieri, Petreczky, Vairo 2008

Laine et al 2007

The singlet static potential and the static energy (pNRQCD)

Example of the type of result
in a given scale hierarchy

Static quark antiquark at $1/r \gg T \gg m_D \gg V$:

energy and width

$$\delta E = \frac{\pi}{9} N_c C_F \, \alpha_s^2 \, r T^2 - \frac{3}{2}\zeta(3)\, C_F \, \frac{\alpha_s}{\pi} \, r^2 \, T \, m_D^2 + \frac{2}{3}\zeta(3)\, N_c C_F \, \alpha_s^2 \, r^2 \, T^3$$

$$\Gamma = \frac{N_c^2 C_F}{3} \, \alpha_s^3 \, T$$

$$- \frac{C_F}{3} \alpha_s \, r^2 \, T \, m_D^2 \left(2\gamma_E - \ln \frac{T^2}{m_D^2} - 1 - 4 \ln 2 - 2 \frac{\zeta'(2)}{\zeta(2)} \right) - \frac{8\pi}{9} \ln 2 \; N_c C_F \, \alpha_s^2 \, r^2 \, T^3$$

- The non-thermal part of the static energy is the Coulomb potential $-C_F \alpha_s / r$.
- The thermal width has two origins. The first term comes from the thermal break up of a quark-antiquark color singlet state into a color octet state. The other terms come from imaginary contributions to the gluon self energy that may be traced back to the Landau damping phenomenon. The first one is specific of QCD, the second one would also show up in QED. Having assumed $m_D \gg V$, the term due to the singlet to octet break up is parametrically suppressed by $(V/m_D)^2$ with respect to the imaginary gluon self-energy contributions.

The singlet static potential and the static energy (pNRQCD)

Example of the type of result
in a given scale hierarchy

Static quark antiquark at $1/r \gg T \gg m_D \gg V$:

energy and width

$$\delta E = \frac{\pi}{9} N_c C_F \alpha_s^2 r T^2 - \frac{3}{2}\zeta(3) C_F \frac{\alpha_s}{\pi} r^2 T m_D^2 + \frac{2}{3}\zeta(3) N_c C_F \alpha_s^2 r^2 T^3$$

$$\Gamma = \frac{N_c^2 C_F}{3} \alpha_s^3 T$$
$$-\frac{C_F}{3}\alpha_s r^2 T m_D^2 \left(2\gamma_E - \ln\frac{T^2}{m_D^2} - 1 - 4\ln 2 - 2\frac{\zeta'(2)}{\zeta(2)}\right) - \frac{8\pi}{9}\ln 2\, N_c C_F \alpha_s^2 r^2 T^3$$

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the logs come from cancellation of divergences
between different scales

The singlet static potential and the dissociation temperature

- The potential is neither the color singlet free energy nor the internal energy
- The quarkonium dissociation is a consequence of the apparence of a thermal decay width rather than being due to the color screening of the real part of the potential

The imaginary part is bigger than the real part before the screening exp{-m_D r} sets in

->the imaginary part is responsible for QQbar dissociation !

$T \gg 1/r \gg m_D \gg V$:Quarkonium melts in the medium

$$E_{\rm binding} \sim \Gamma$$

$$\pi T_{\rm melting} \sim m\, g^{4/3}$$

Escobedo Soto arXiv:0804.0691

Laine arXiv:0810.1112

- When $\langle 1/r \rangle \sim m_D$, the interaction is screened; note that

$$\pi T_{\rm screening} \gg \pi T_{\rm dissociation}$$

The dissociation temperature

The $\Upsilon(1S)$ dissociation temperature:

m_c (MeV)	$T_{\rm dissociation}$ (MeV)
∞	480
5000	480
2500	460
1200	440
0	420

A temperature πT about 1 GeV is below the dissociation temperature.

◦ Escobedo Soto PRA 82 (2010) 042506

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The singlet static potential and the static energy (pNRQCD)

- Temperature effects can be other than screening

$T > 1/r$ and $1/r \sim m_D \sim gT$

exponential screening but $\mathrm{Im}V \gg \mathrm{Re}V$

$T > 1/r$ and $1/r > m_D \sim gT$

no exponential screening but
power-like T corrections

or

$$\frac{1}{r} > T > V$$

$$T < V$$

no thermal corrections to the potential,
thermal corrections to the energy

Application of the EFT: bottomonium 1S below the melting temperature T_d at LHC

The relative size of non-relativistic and thermal scales depends on the medium and on the quarkonium state.

The bottomonium ground state , which is a weakly coupled non-relativistic bound state: $mv \sim m\alpha_s$, $mv^2 \sim m\alpha_s^2 \gtrsim \Lambda_{QCD}$, produced in the QCD medium of heavy-ion collisions at the LHC may possibly realize the hierarchy

$$m \approx 5 \text{ GeV} > m\alpha_s \approx 1.5 \text{ GeV} > \pi T \approx 1 \text{ GeV} > m\alpha_s^2 \approx 0.5 \text{ GeV} \gtrsim m_D, \Lambda_{QCD}$$

Vairo AIP CP 1317 (2011) 241 N.B., Escobedo, Ghiglieri, Soto ,Vairo 010

The effective field theory allows us to calculate systematically the contribution from each scale to the energy level and width

thermal contributions to the levels calculated at order malpha^5

case of interest for LHC: bottomonium 1S below the melting temperature T_d

The complete mass and width up to $\mathcal{O}(m\alpha_s^5)$

$$\delta E_{1S}^{(\mathrm{thermal})} = \frac{34\pi}{27}\alpha_s^2 T^2 a_0 + \frac{7225}{324}\frac{E_1\alpha_s^3}{\pi}\left[\ln\left(\frac{2\pi T}{E_1}\right)^2 - 2\gamma_E\right] + \frac{128 E_1\alpha_s^3}{81\pi}L_{1,0} - 3a_0^2\left\{\left[\frac{6}{\pi}\zeta(3) + \frac{4\pi}{3}\right]\alpha_s T\, m_D^2 - \frac{8}{3}\zeta(3)\,\alpha_s^2 T^3\right\}$$

$$\Gamma_{1S}^{(\mathrm{thermal})} = \frac{1156}{81}\alpha_s^3 T + \frac{7225}{162}E_1\alpha_s^3 + \frac{32}{9}\alpha_s T m_D^2\, a_0^2\, I_{1,0} - \left[\frac{4}{3}\alpha_s T m_D^2\left(\ln\frac{E_1^2}{T^2} + 2\gamma_E - 3 - \ln 4 - 2\frac{\zeta'(2)}{\zeta(2)}\right) + \frac{32\pi}{3}\ln 2\,\alpha_s^2 T^3\right]a_0^2$$

where $E_1 = -\frac{4m\alpha_s^2}{9}$, $a_0 = \frac{3}{2m\alpha_s}$ and $L_{1,0}$ (similar $I_{1,0}$) is the Bethe logarithm.

- Brambilla Escobedo Ghiglieri Soto Vairo JHEP 1009 (2010) 038

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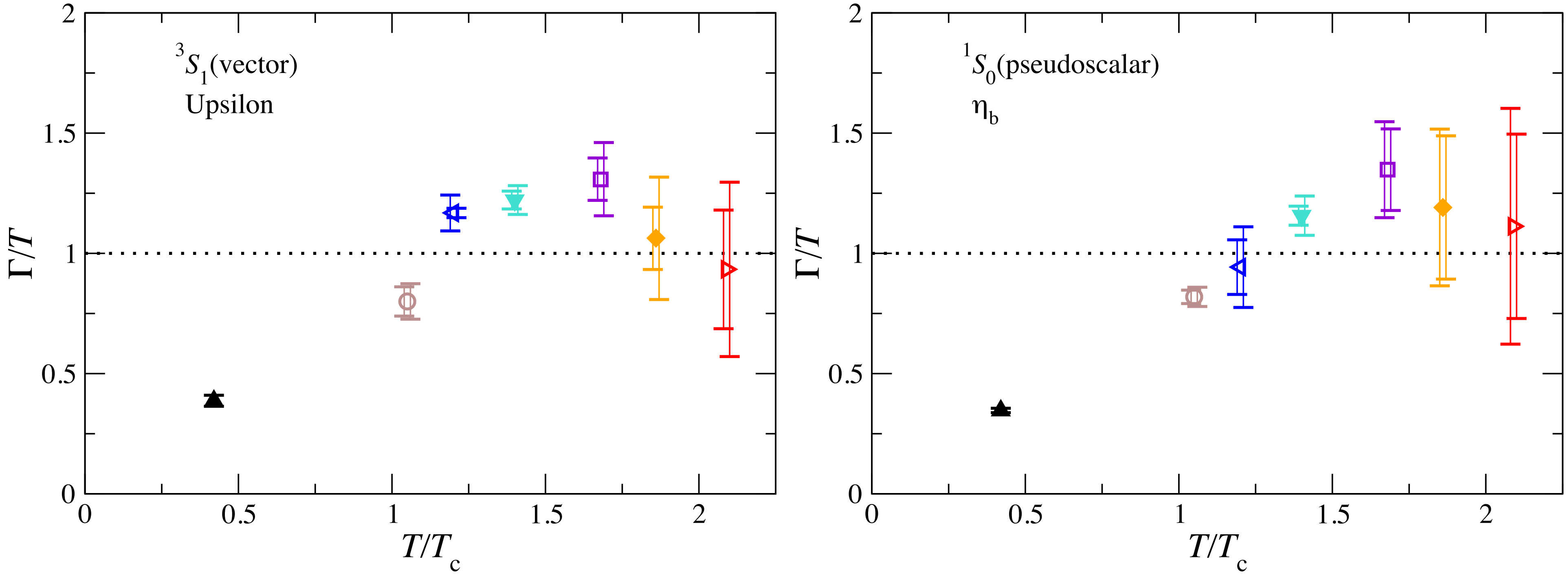
quarkonium mass increases quadratically with T

$$\Gamma_{1S}^{(\mathrm{thermal})} = \frac{1156}{81}\alpha_s^3 T + \frac{7225}{162}E_1\alpha_s^3 + \frac{32}{9}\alpha_s T m_D^2\, a_0^2\, I_{1,0} - \left[\frac{4}{3}\alpha_s T m_D^2\left(\ln\frac{E_1^2}{T^2} + 2\gamma_E - 3 - \ln 4 - 2\frac{\zeta'(2)}{\zeta(2)}\right) + \frac{32\pi}{3}\ln 2\,\alpha_s^2 T^3\right] a_0^2$$

decay width linear in temperature

- Electromagnetic decays occur at short distances $\sim 1/m \ll 1/T$, hence the standard NRQCD factorization formulas hold. At leading order, all the temperature dependence is encoded in the wave function at the origin. The leading temperature correction to it can be read from the potential and is of order $\sim n^4 T^2/(m^2\alpha_s)$. Hence, a quadratic dependence on the temperature should be observed in the frequency of produced leptons or photons.

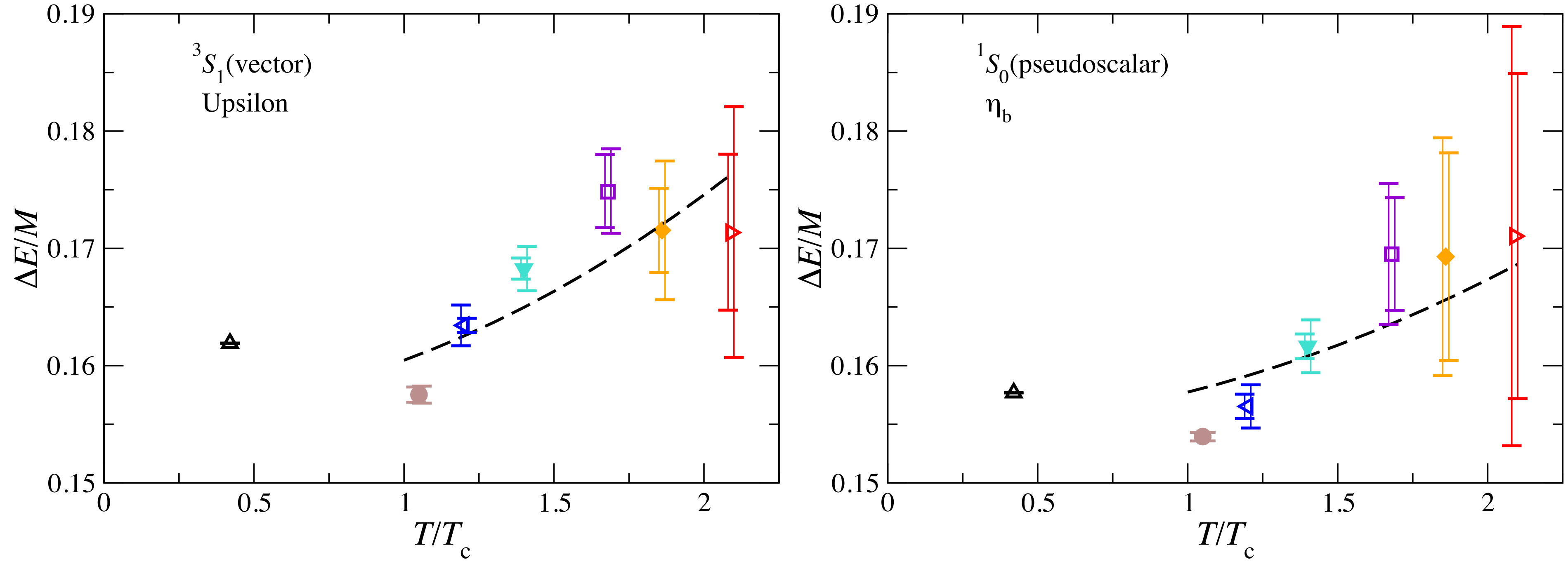
Lattice width



Consistent with $\Gamma_{1S}^{(\text{thermal})} = \frac{1156}{81}\alpha_s^3 T \quad \Rightarrow \alpha_s \approx 0.4.$

- Aarts Allton Kim Lombardo Oktay Ryan Sinclair Skullerud JHEP 1111 (2011) 103

Lattice energy



Consistent with $\delta E_{1S}^{(\text{thermal})} = \frac{17\pi}{9}\alpha_s \frac{T^2}{m}$ using $\alpha_s = 0.4$ and $m = 5$ GeV.

- Aarts Allton Kim Lombardo Oktay Ryan Sinclair Skullerud JHEP 1111 (2011) 103

Conclusions I

- In a framework that makes close contact with modern effective field theories for non-relativistic bound states at zero temperature, we have studied the real-time evolution of a static quark-antiquark pair in a medium of gluons and light quarks at finite temperature.

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- Two mechanisms contribute to the thermal decay width: the imaginary part of the gluon self energy induced by the Landau damping phenomenon, and the quark-antiquark color singlet to color octet thermal break up. Parametrically, the first mechanism dominates for temperatures such that the Debye mass m_D is larger than the binding energy, while the latter dominates for temperatures such that m_D is smaller than the binding energy.

Conclusions II

- We have studied in detail the situation: $m\alpha_s \gg \pi T \gg m\alpha_s^2 \gtrsim m_D$ that may be relevant for the bottomonium $1S$ states at the LHC.

$$m_b\alpha_s \approx 1.5 \text{ GeV} > \pi T \approx 1 \text{ GeV} > m\alpha_s^2 \approx 0.5 \text{ GeV} \gtrsim m_D$$

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- At leading order, a decay width linear with temperature is developed, which implies a tendency to decay to the continuum of colour-octet states. Hence, a consistently smaller number of vector and pseudoscalar ground states is expected to be in the sample with respect to the zero temperature case.

Quasi-free dissociation

For general T, the thermal width due to Landau damping reads

$$\Gamma_{1S} = \sum_p \int_{q_{\rm min}} \frac{d^3q}{(2\pi)^3}\, f_p(|\mathbf{q}|)(1 \pm f_p(|\mathbf{q}|))\, \sigma_{1S}(|\mathbf{q}|)\,,$$

where the sum runs over the different incoming light partons and $f_g = n_{\rm B}$ or $f_q = n_{\rm F}$.

σ_{1S} is known as the quarkonium quasi-free dissociation cross section.
The thermal NR EFTs provide analytic expressions of σ_{1S} for different temperatures.

- `Brambilla Escobedo Ghiglieri Vairo TUM-EFT 27/11`

Quasi-free dissociation: previous literature

In the previous literature, it was assumed

$$\Gamma_{1S} = \sum_p \int_{q_{\min}} \frac{d^3q}{(2\pi)^3} \; f_p(|\mathbf{q}|) \, \sigma_{\mathrm{HQ}}(|\mathbf{q}|) \, ,$$

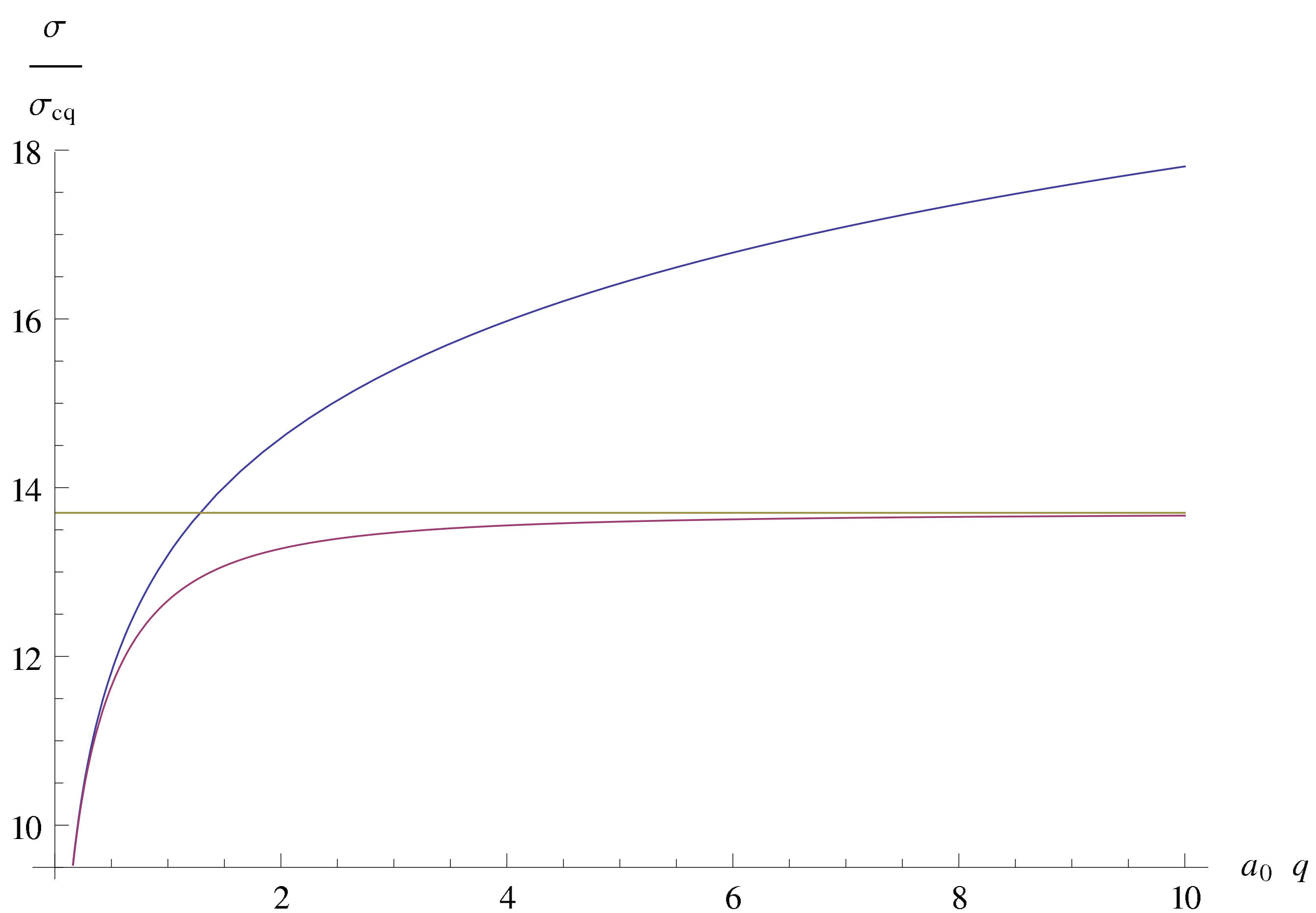
with $\sigma_{\mathrm{HQ}} = 2\sigma_c$, where σ_c is the cross section for the process $pc \to pc$ at $T = 0$.

○ `Grandchamp Rapp, PLB 523 (2001) 60, ...`

The EFT analysis proves this assumption to be incorrect, because

- the dependence on the thermal distributions of the incoming and outgoing partons is different;
- σ_{1S} cannot be identified with σ_{HQ}, moreover it is temperature dependent.

Quasi-free dissociation: light-quark contribution



$m_D a_0 = 0.001$

blue line: $mv \gg T \gg m_D \gg E$
(dipole approximation)

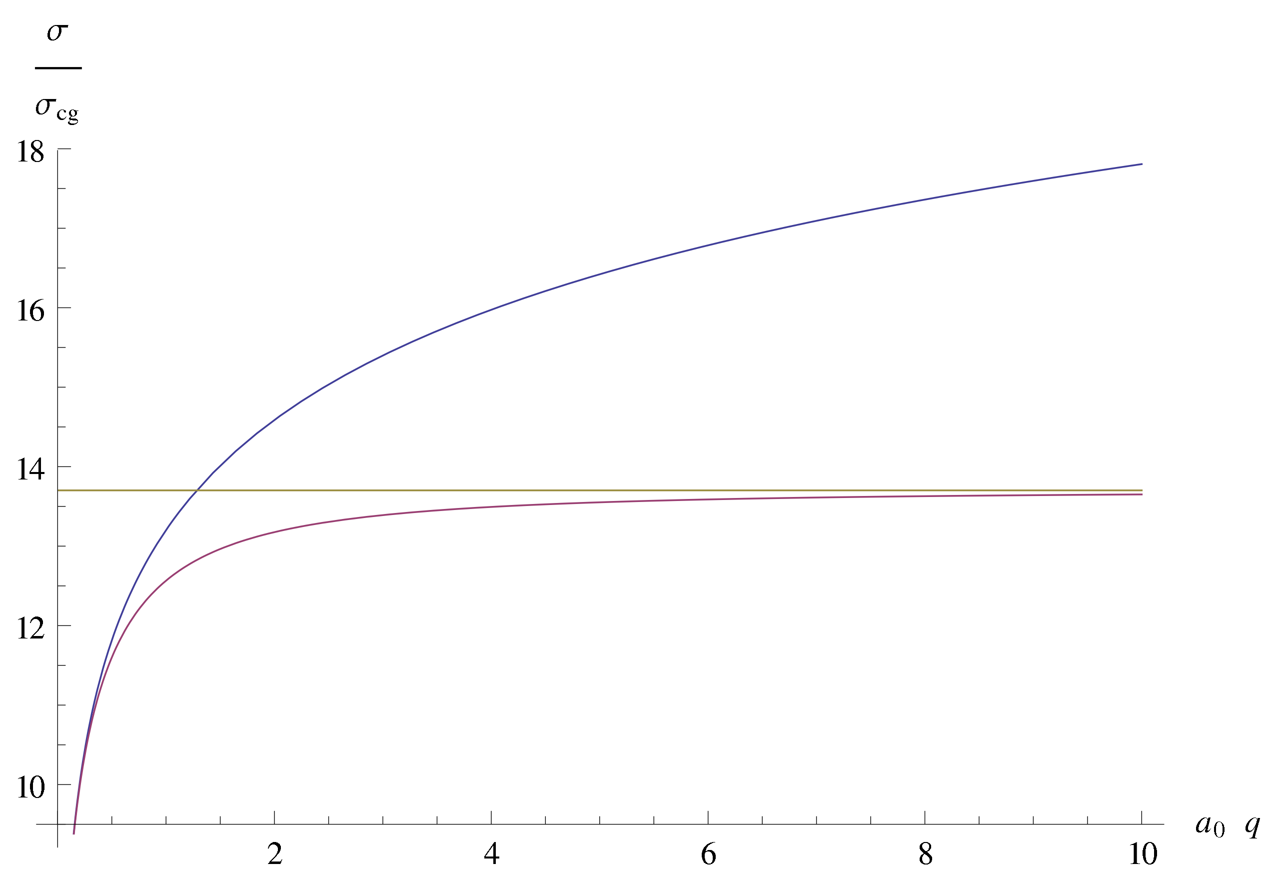
pink line: $T \sim mv \gg m_D$

yellow line: $T \gg mv \sim m_D$

$\sigma_{cq} \equiv 8\pi C_F n_f\, \alpha_{\rm s}^2\, a_0^2$

- Brambilla Escobedo Ghiglieri Vairo TUM-EFT 27/11

Quasi-free dissociation: gluon contribution



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blue line: $mv \gg T \gg m_D \gg E$
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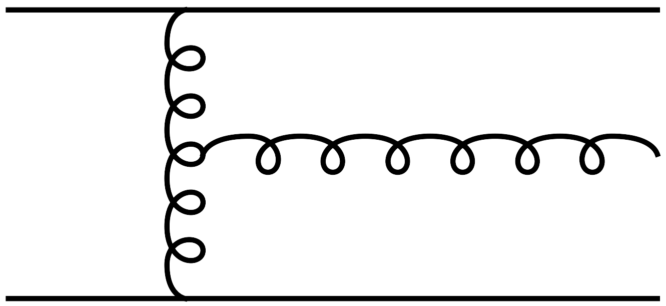
pink line: $T \sim mv \gg m_D$
yellow line: $T \gg mv \sim m_D$

$\sigma_{cg} \equiv 8\pi C_F N_c\, \alpha_s^2\, a_0^2$

- Brambilla Escobedo Ghiglieri Vairo TUM-EFT 27/11

Singlet to octet break up

The thermal width at the scale E, which is of order $\alpha_s^3 T$, is generated by the break up of a quark-antiquark color-singlet state into an unbound quark-antiquark color-octet state: a process that is kinematically allowed only in a medium.



- The singlet to octet break up is a different phenomenon with respect to the Landau damping, the relative size of which is $(E/m_D)^2$. In the situation $m\alpha_s^2 \gg m_D$, the first dominates over the second by a factor $(m\alpha_s^2/m_D)^2$.

○ Brambilla Ghiglieri Petreczky Vairo PRD 78 (2008) 014017

Gluodissociation

For general T, the thermal width due to $\mathrm{S} \to \mathrm{O} + g$ break up in a medium reads

$$\Gamma_{1S} = \int_{|\mathbf{q}| \geq |E_{1S}|} \frac{d^3q}{(2\pi)^3}\, n_{\mathrm{B}}(|\mathbf{q}|)\, \sigma_{1S}(|\mathbf{q}|) \xrightarrow[T \gg E]{} \text{previous slide}$$

with

$$\sigma_{1S}(|\mathbf{q}|) = \frac{\alpha_{\mathrm{s}} C_F}{3} 2^{10} \pi^2 \rho (\rho+2)^2 \frac{E_1^4}{m|\mathbf{q}|^5} \left(t(|\mathbf{q}|)^2 + \rho^2\right) \frac{\exp\left(\frac{4\rho}{t(|\mathbf{q}|)} \arctan\left(t(|\mathbf{q}|)\right)\right)}{e^{\frac{2\pi\rho}{t(|\mathbf{q}|)}} - 1}$$

where $\rho \equiv 1/(N_c^2 - 1)$ and $t(|\mathbf{q}|) \equiv \sqrt{|\mathbf{q}|/|E_1| - 1}$.

σ_{1S}, which is the cross section of the process $\mathrm{S} \to \mathrm{O} + g$ in the vacuum, is known as the quarkonium gluodissociation cross section.

- Brambilla Escobedo Ghiglieri Vairo JHEP 1112 (2011) 116
  Brezinski Wolschin PLB 707 (2012) 534

Gluodissociation: the Bhanot–Peskin approximation

In the large N_c limit:

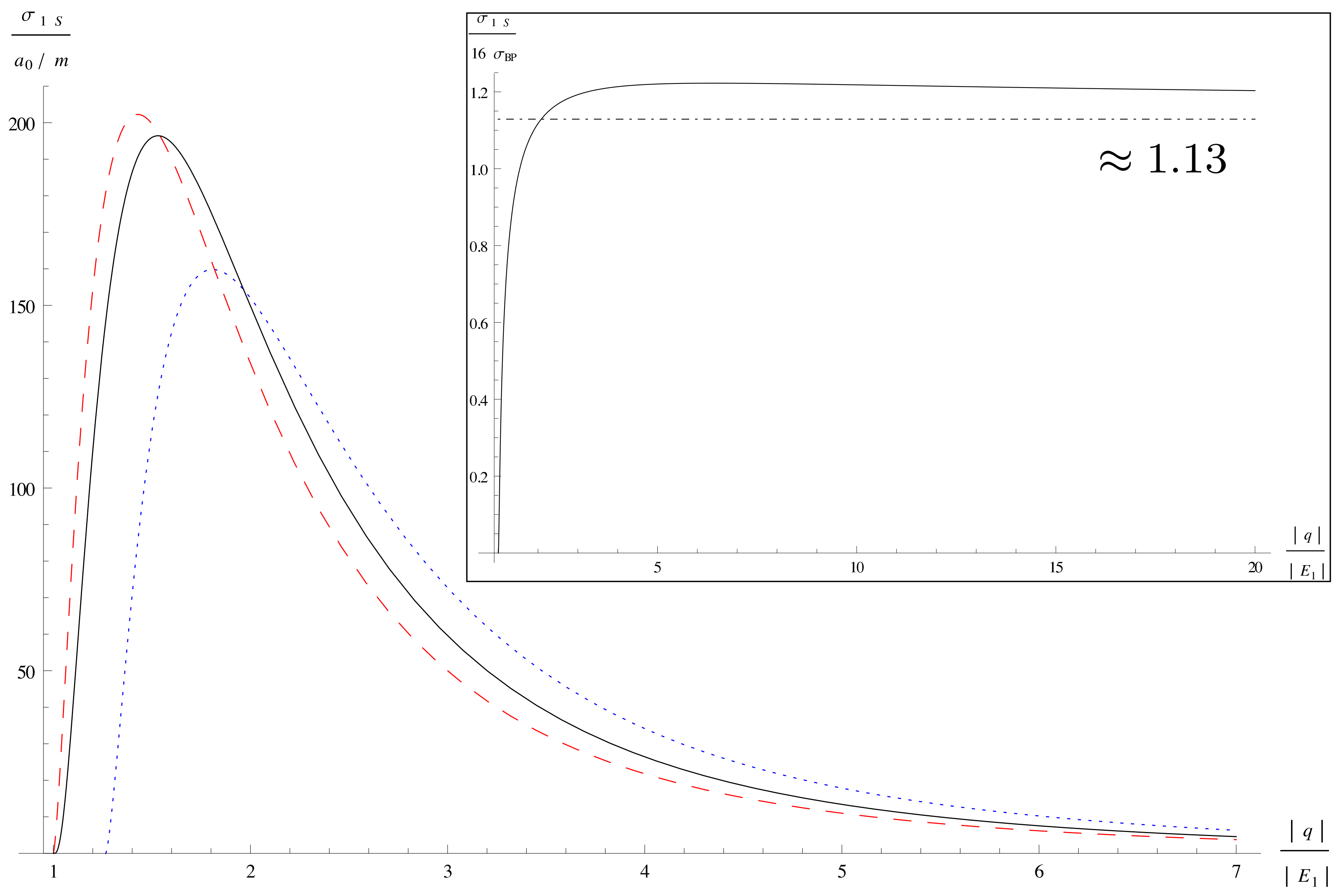
$$\sigma_{1S}(|\mathbf{q}|) \xrightarrow[N_c\to\infty]{} 16\,\frac{2^9\pi\alpha_s}{9}\,\frac{|E_1|^{5/2}}{m}\,\frac{(|\mathbf{q}|+E_1)^{3/2}}{|\mathbf{q}|^5} = 16\,\sigma_{1S,\mathrm{BP}}(|\mathbf{q}|)$$

$$\Gamma_{1S} \xrightarrow[N_c\to\infty]{} \int_{|\mathbf{q}|\geq|E_1|}\frac{d^3q}{(2\pi)^3}\,n_{\mathrm{B}}(|\mathbf{q}|)\,16\,\sigma_{1S,\mathrm{BP}}(|\mathbf{q}|) = \Gamma_{1S,\mathrm{BP}}$$

- `Bhanot Peskin NPB 156 (1979) 391`

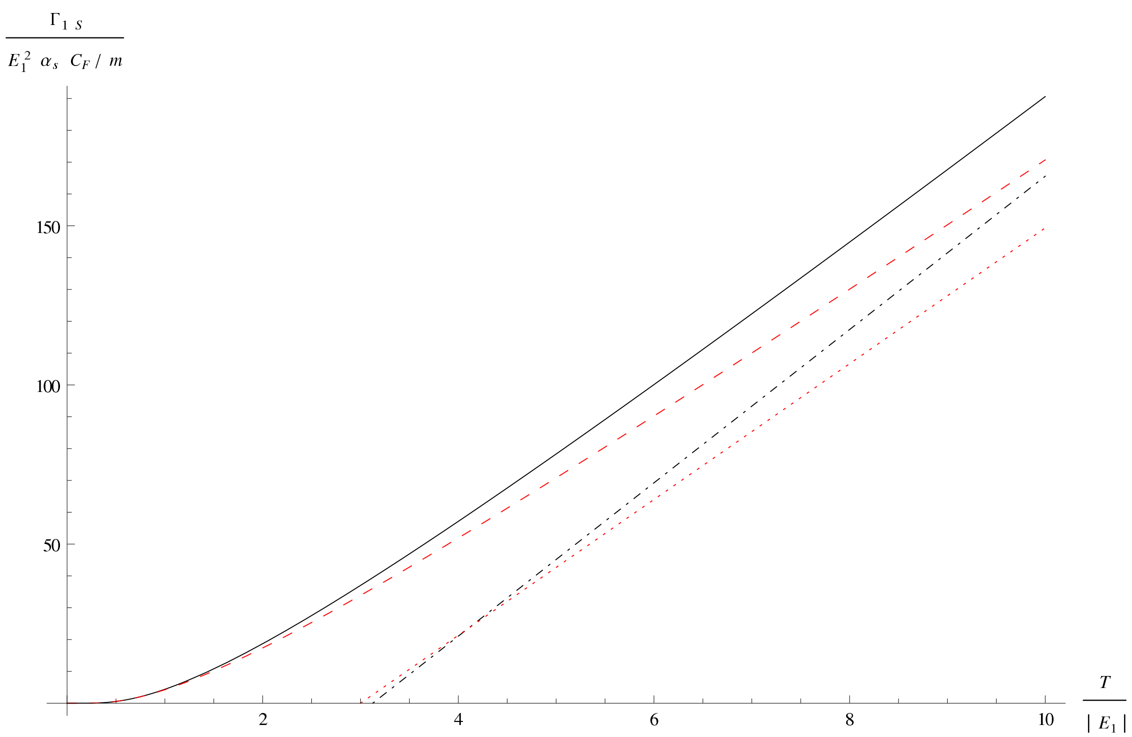
The Bhanot–Peskin (BP) approximation corresponds to neglecting final state interactions, i.e. the rescattering of a $Q\bar{Q}$ pair in a color octet configuration.

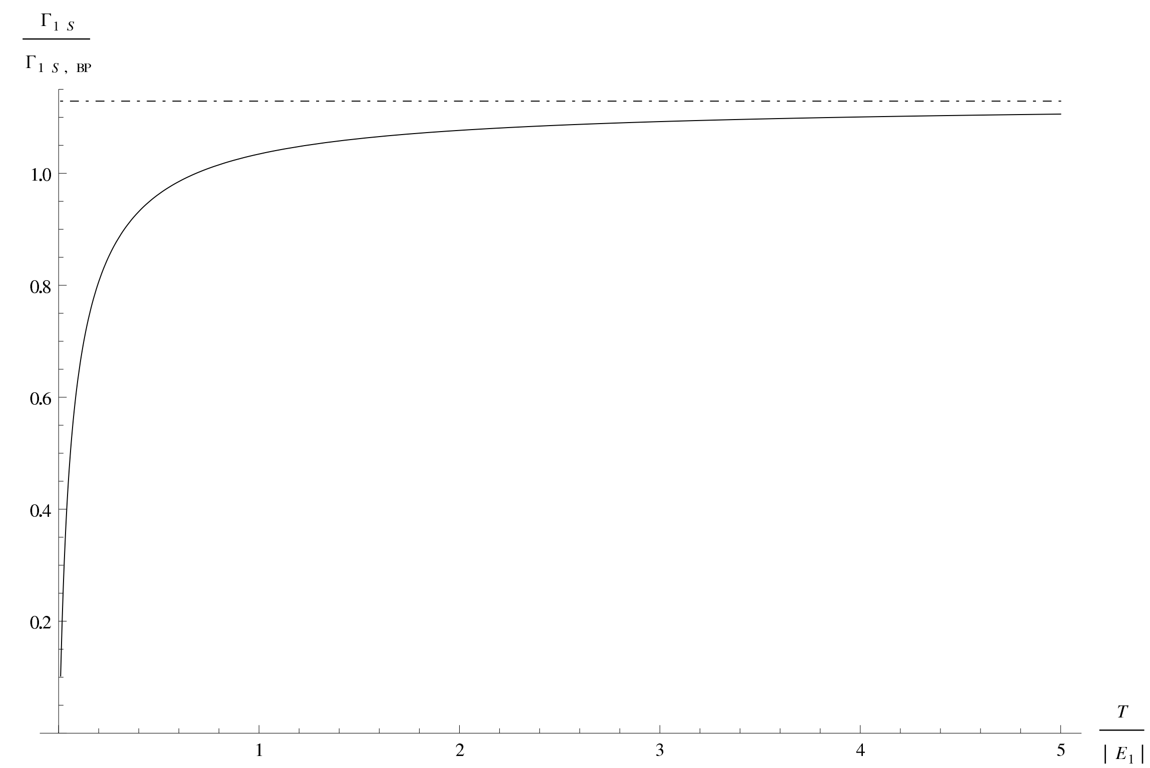
Gludissociation: full cross section vs BP cross section



- Brambilla Escobedo Ghiglieri Vairo JHEP 1112 (2011) 116

Gluodissociation: full width vs BP width





Lines on the left correspond to the $T \gg |E_1|$ analytic results of the previous slides.

- Brambilla Escobedo Ghiglieri Vairo JHEP 1112 (2011) 116

The QQbar interaction in the medium: recent developments

The quarkonium static potential has been calculated for $T \gg 1/r \gtrsim m_D$ by performing an analytical continuation to real time of the Euclidean Wilson loop computed in imaginary time. The calculation is done in weak-coupling resummed perturbation theory.

- Laine Philipsen Romatschke Tassler JHEP 0703(2007)054
- Laine Philipsen Tassler JHEP 0709(2007)066
- Laine JHEP 0705(2007)028
- Burnier Laine Vepsalainen JHEP 0801(2008)043

Static particles in a hot QED plasma, in real-time formalism, have been considered in the situation $1/r \sim m_D$, confirming previous results.

- Beraudo Blaizot Ratti NPA 806(2008)312

- A comprehensive study of non-relativistic bound states in a hot QED plasma in a non-relativistic EFT framework has been performed for a wide range of temperatures: from $T \ll m$ to $T \sim m$.

- Escobedo Soto PRA 78(2008)032520, Escobedo at this workshop ArXiv:1008.0254

Here I will report about a comprehensive EFT study of QQbar interaction, spectrum, decays at finite T in real time

N. Brambilla, J. Ghiglieri, P. Petreczky and A. Vairo Phys. Rev. D 78 (2008) 014017

N. Brambilla, M. Escobedo, J. Ghiglieri, J. Soto and A. Vairo ArXiv:1007.4156