Title: Quarkonium Suppression in QGP via String Theory

Date: May 23, 2007 05:20 PM

URL: http://pirsa.org/07050063

Abstract:

Quarkonium in a thermal medium via string theory

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Qudsia Ejaz, Thomas Faulkner, HL, Krishna Rajagopal, Urs Wiedemann

hep-ph/0607062, hep-ph/0612168, and to appear

Quarkonium dissociation in QGP

Above T_C, light-quark mesons no longer exist due to deconfinement.

Heavy quarkonium may still exist above T_C and dissociate at a higher temperature T_d (due to color screening), e.g.

$$J/\psi\,(\overline{c}\,c):T_d \sim 2\,T_C$$

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Quarkonium suppression is a sensitive probe of QGP.

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Lattice: static quark potential, spectral functions

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3. Speculations:

   What would happen in QCD?

AdS/CFT correspondence

Maldacena (1997), Gubser, Klebanov, Polyakov; Witten (1998)

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$\mathcal{N} = 4$ Super-Yang-Mills theory in 4d with SU(N_C) $\Longleftrightarrow$ IIB string theory in $AdS_5 \times S_5$

AdS/CFT correspondence

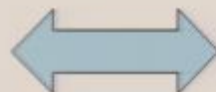Maldacena (1997), Gubser, Klebanov, Polyakov; Witten (1998)

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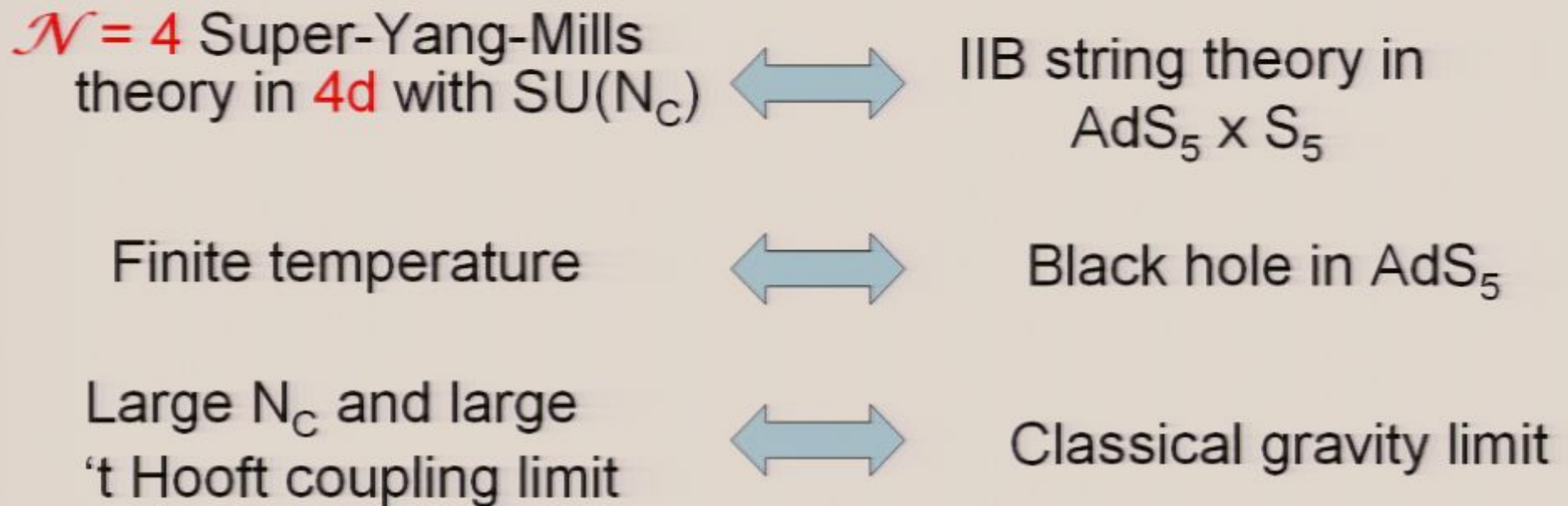
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$r = \infty$

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event horizon   **BH extends in (3+1) directions**

External quarks in $\mathcal{N}$=4 SYM at finite T

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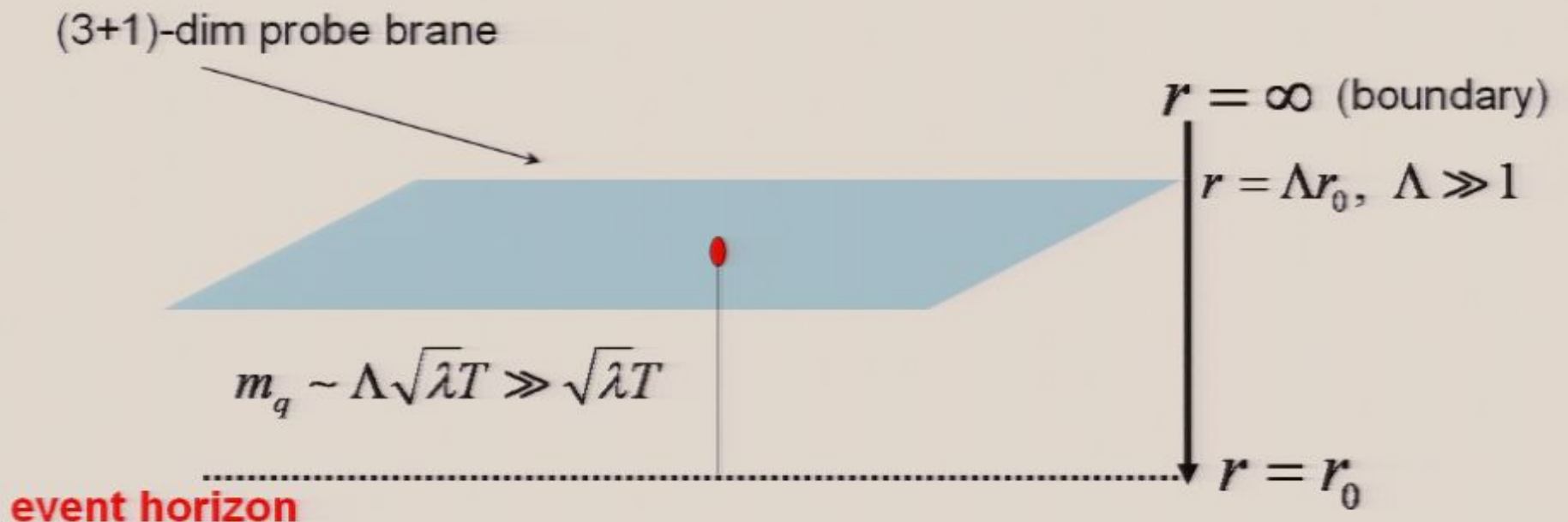
Static quark potential in $\mathcal{N}$=4 SYM

Maldacena;
Rey, Yee;
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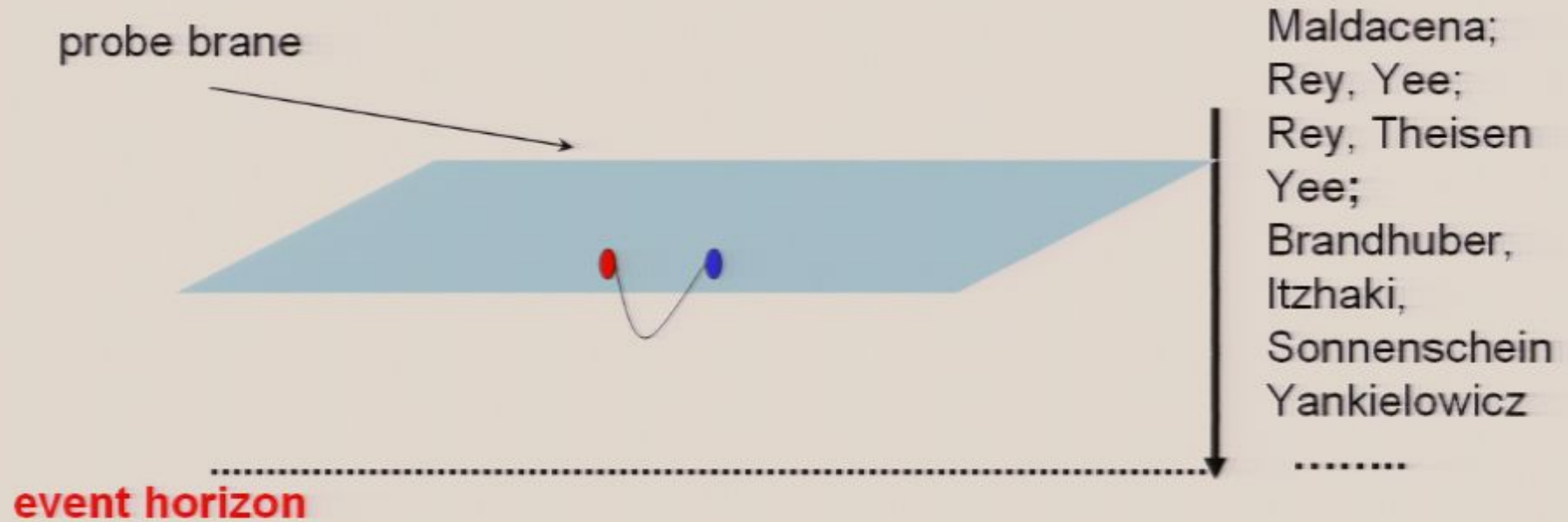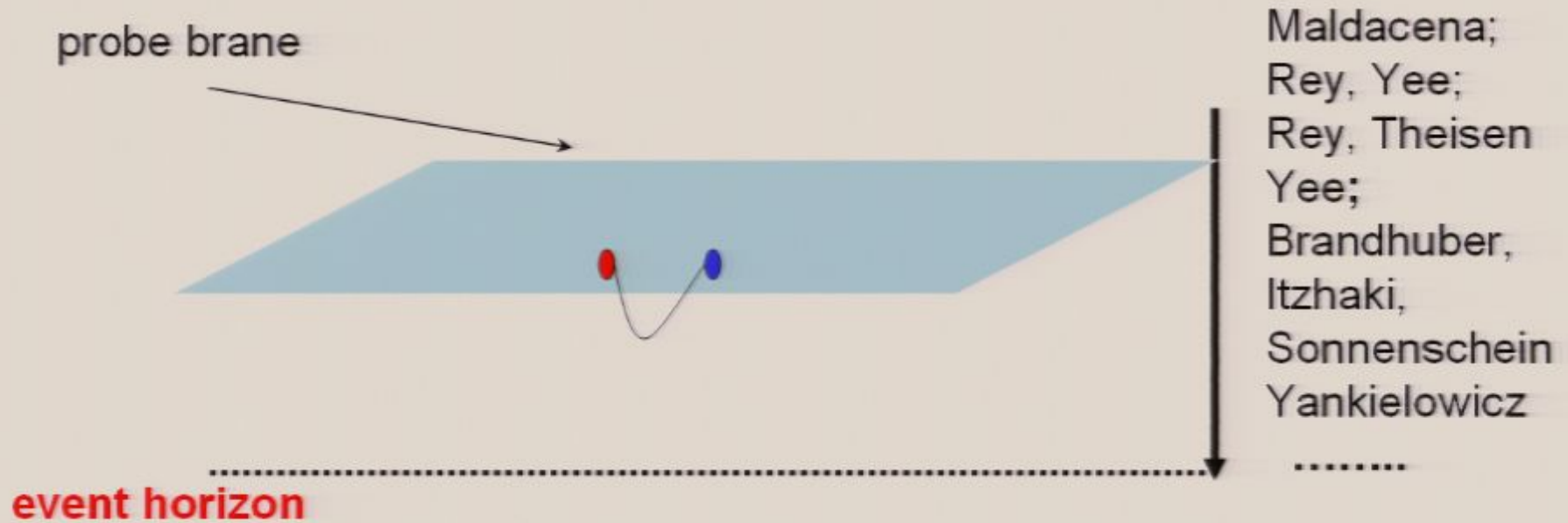
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quark potential = energy of open string connecting the pair

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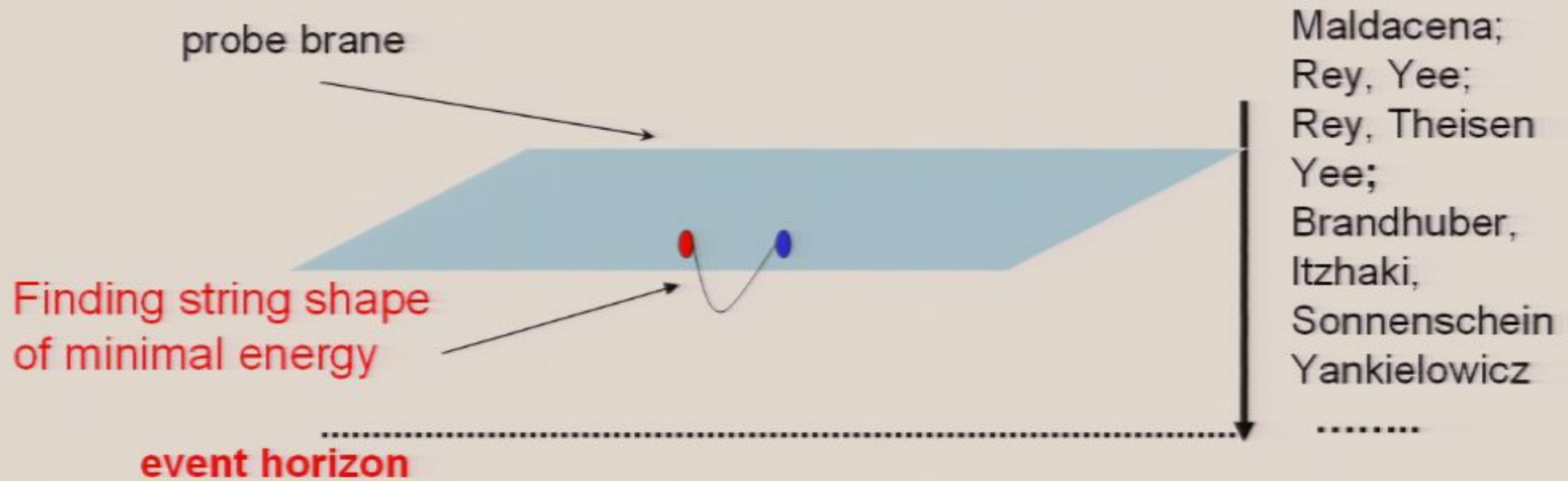
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Finding string shape
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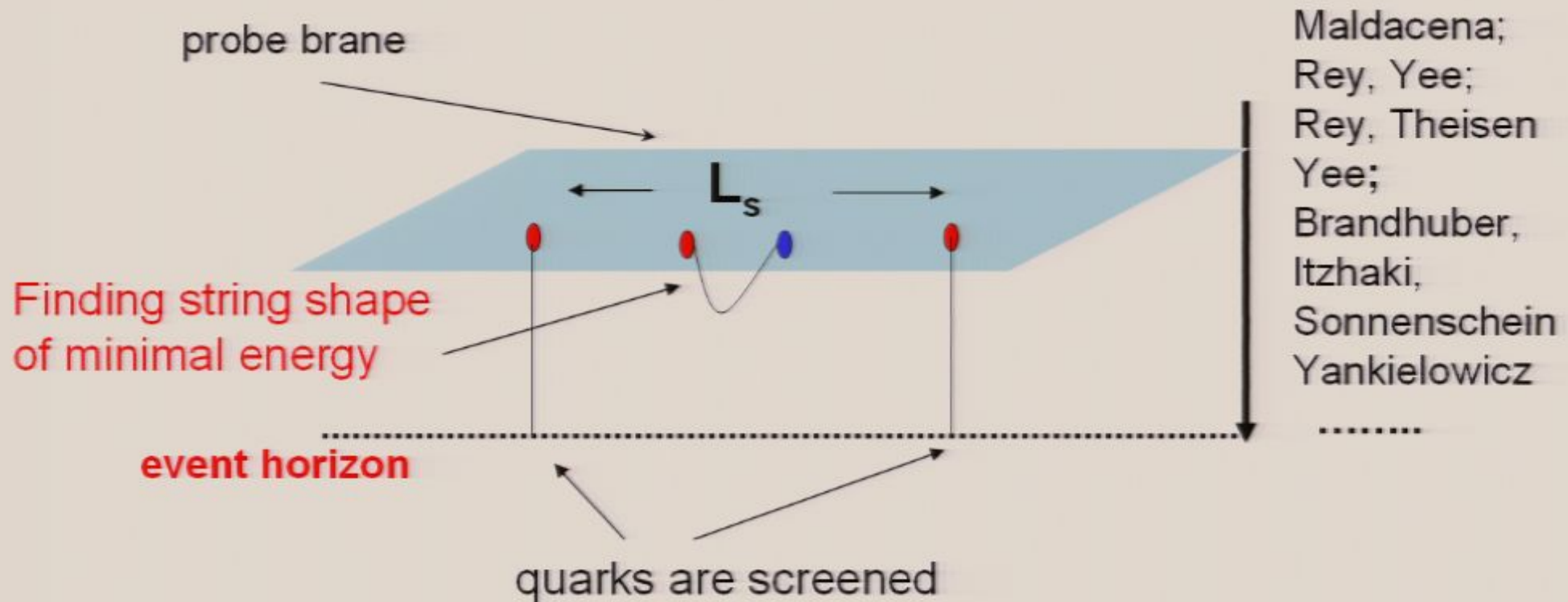
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quarks are screened

In the large N_c and large $\lambda = g_{YM}^2 N_c$ limit:

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$$V(L) \propto \sqrt{\lambda} f(TL), \qquad L_S = 0.277/T$$

Quark potential at finite velocity

HL,
Rajagopal
Wiedemann

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Moving at a finite velocity v

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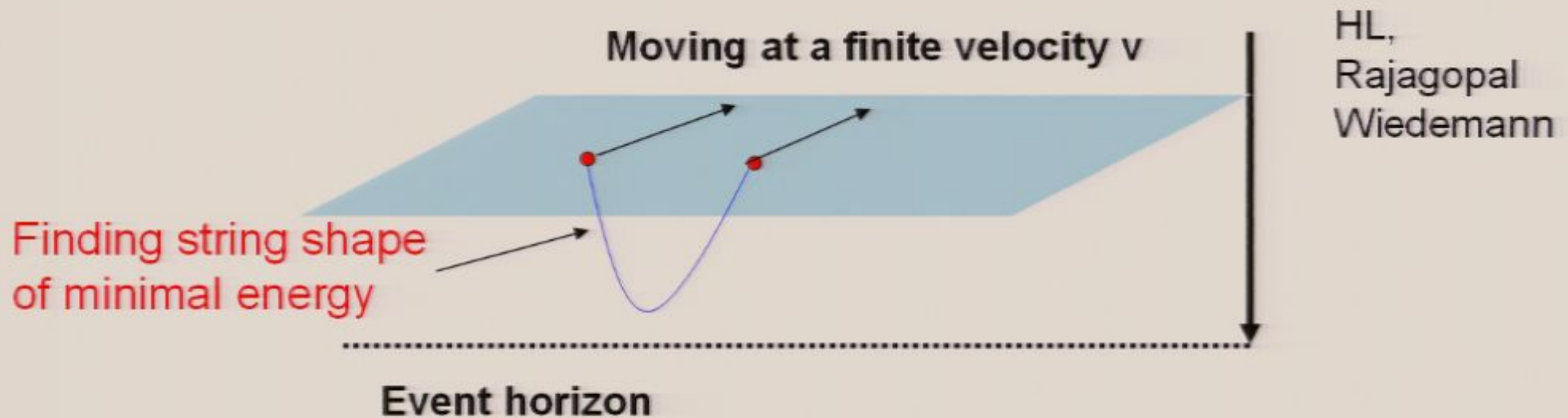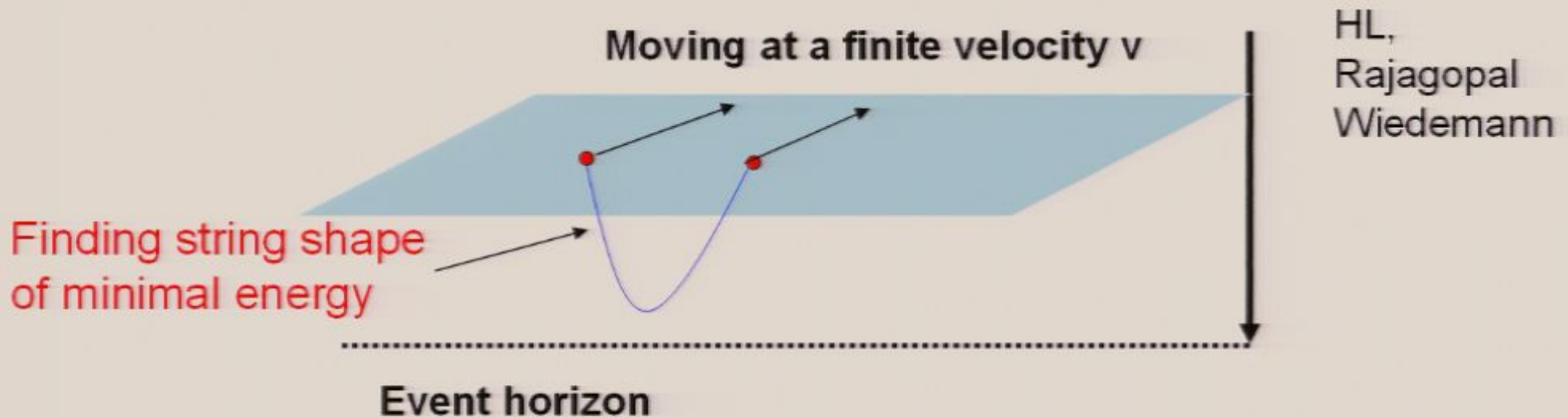
$$L_s(v) \approx L_s(0) \, (1 - v^2)^{1/4} \sim (1 - v^2)^{1/4} \frac{1}{T} \sim \frac{1}{(1 - v^2)^{-\frac{1}{4}} T}$$

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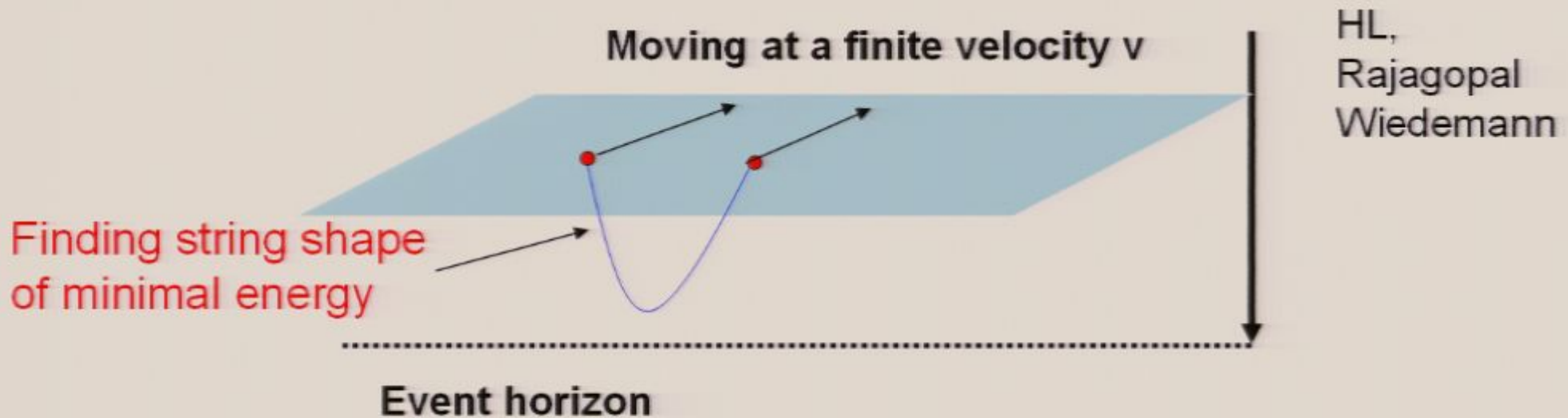
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In a rest frame of quark pair, the medium is boosted:

$$\varepsilon(v) = \left(\frac{1}{\sqrt{1-v^2}}\right)^2 \varepsilon(0) \sim \left(\frac{1}{\sqrt{1-v^2}}\right)^2 T^4 \sim \left((1-v^2)^{-\frac{1}{4}}T\right)^4$$

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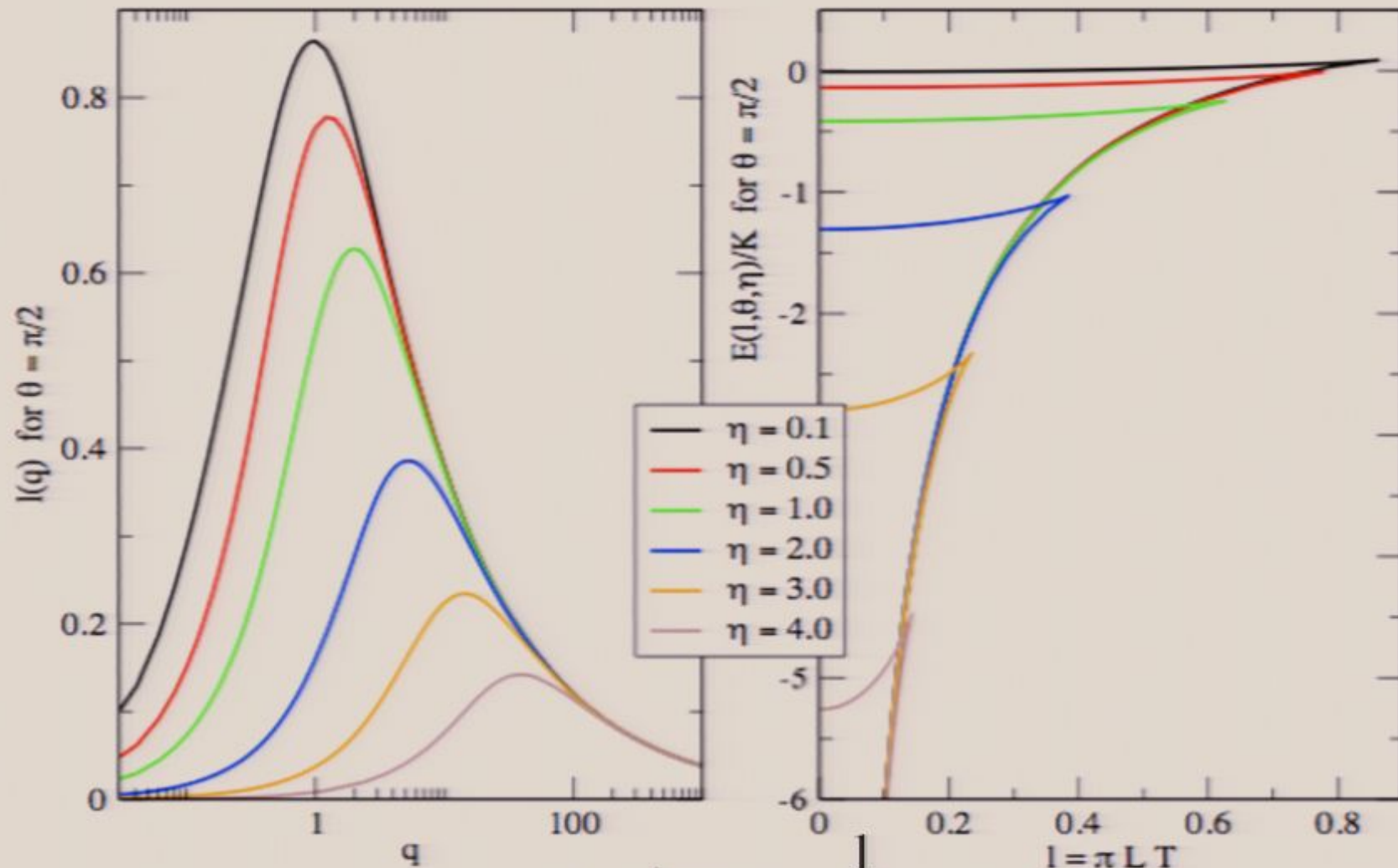
$$\cosh \eta = \frac{1}{\sqrt{1-v^2}}$$

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What would happen if QCD also has similar velocity scaling?

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Karsch, Kharzeev, Satz,

RHIC has not reached T_d for J/ψ.

Quarkonium suppression:
a prediction via string theory

HL,Rajagopal,Wiedemann

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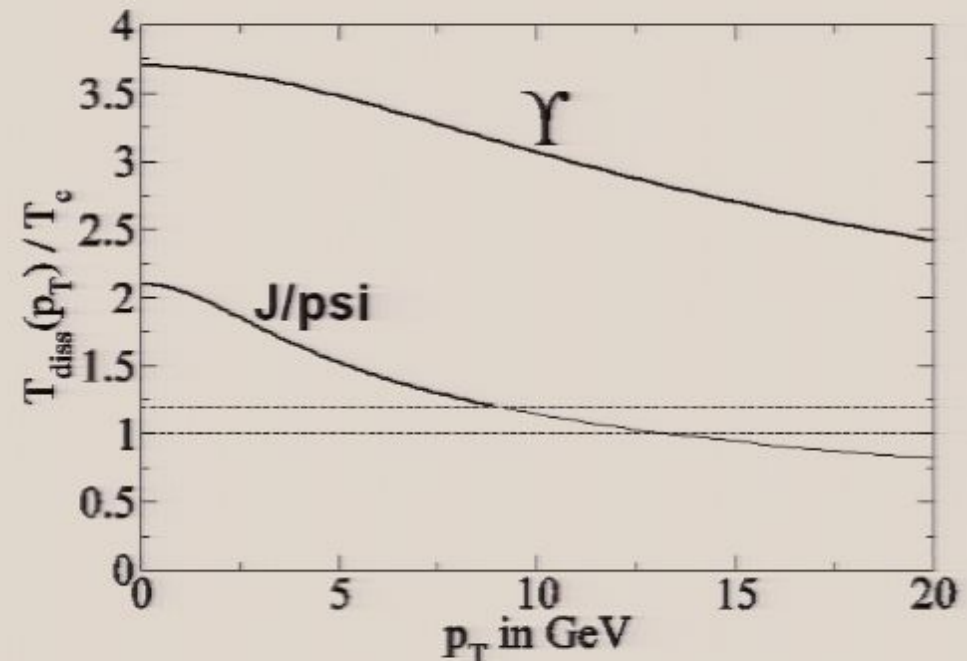
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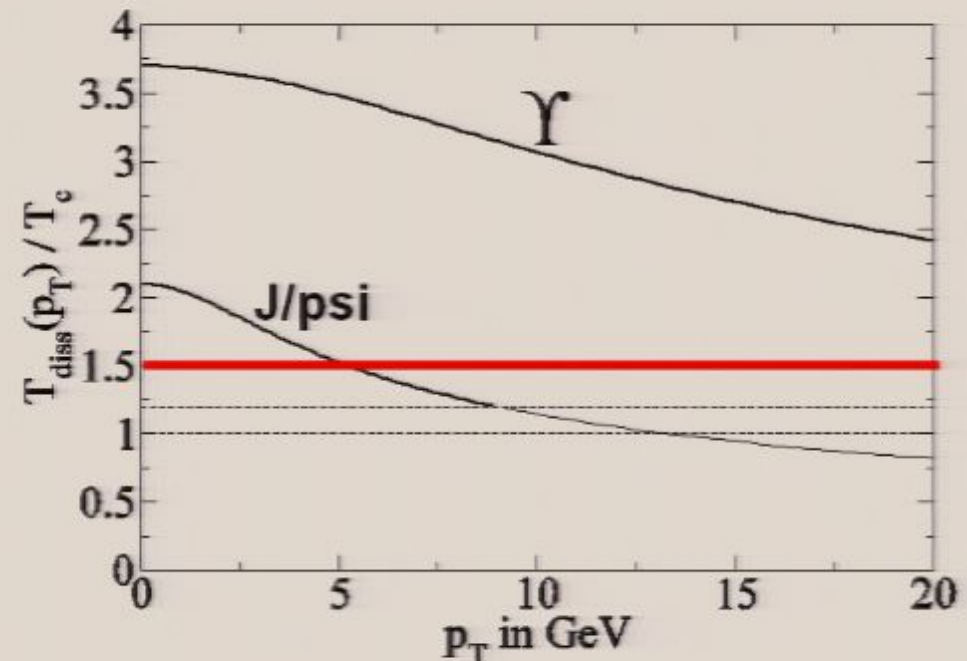
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Quarkonium suppression: a prediction via string theory

HL, Rajagopal, Wiedemann

Heavy quark mesons with larger velocity dissociate at a lower temperature.

$$T_d(v) \sim (1-v^2)^{1/4} T_d(0)$$

Expect significant suppression at large P_T.

This effect may be significant and tested at RHIC II or LHC
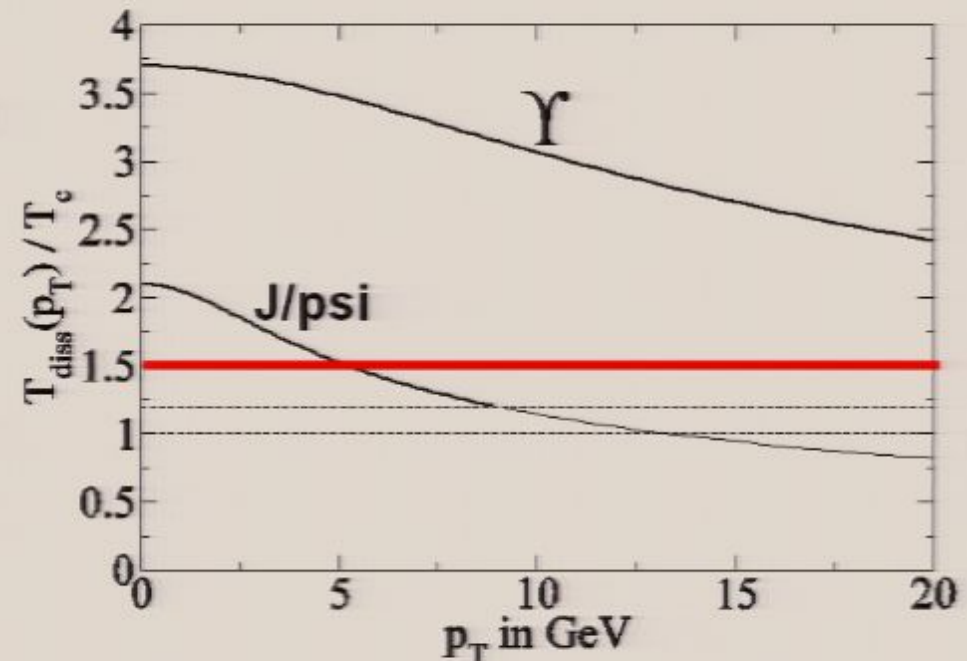
A speed limit

HL,Rajagopal,Wiedemann
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v_C: Local speed of light on the probe brane.

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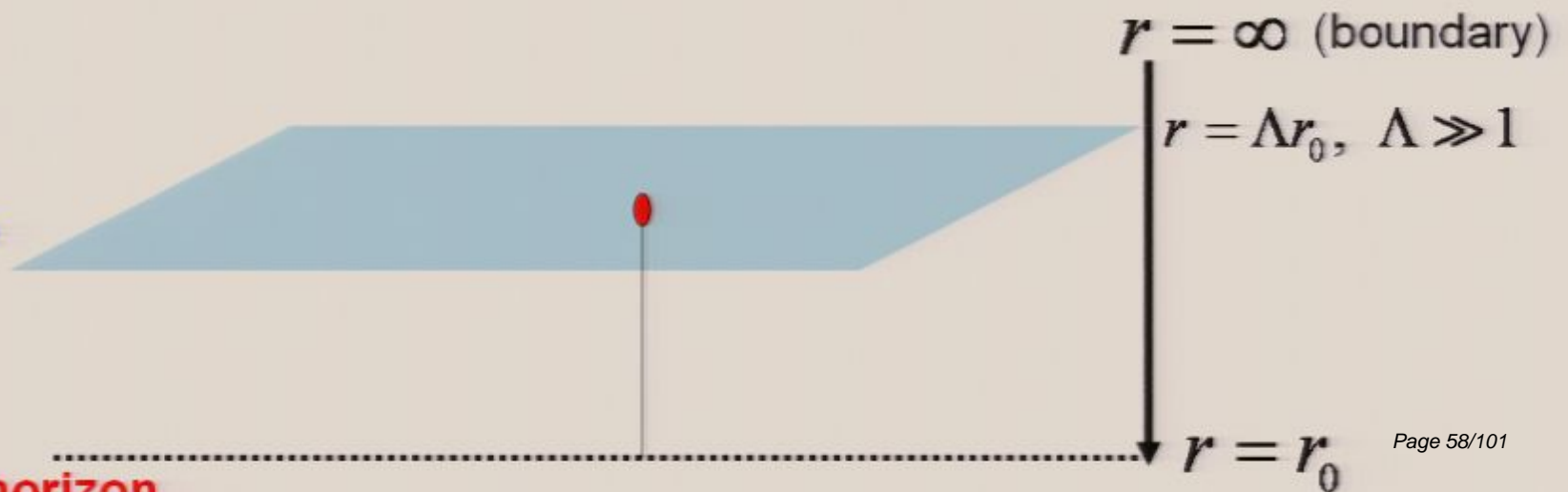
Going beyond the potential model

1. So far have to restrict to $m_q \gg \sqrt{\lambda T}$

   What happens when $m_q \sim \sqrt{\lambda T}$?

2. Information on bound states indirect.

   It would be ideal to study mesons directly.

Adding flavors in AdS/CFT

Karch, Katz

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D7

m_q

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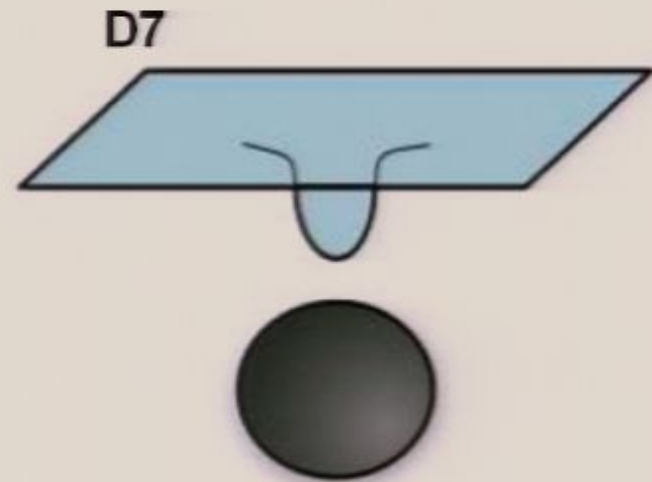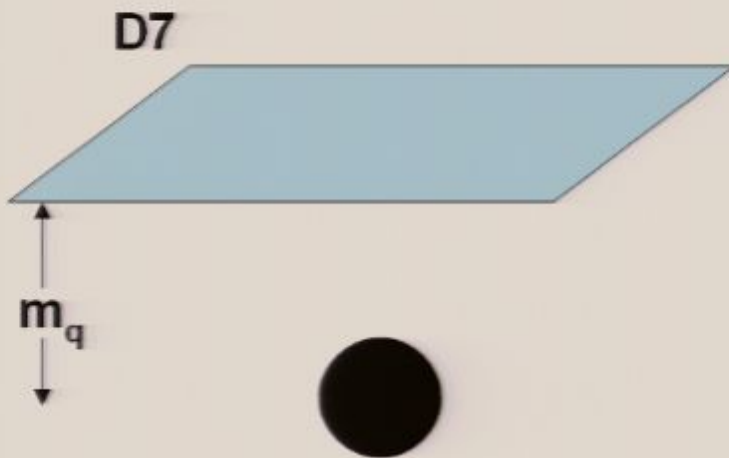
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Lowest lying mesons:
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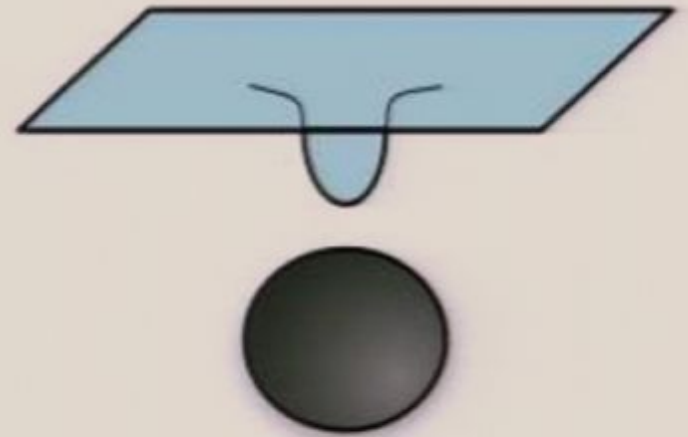
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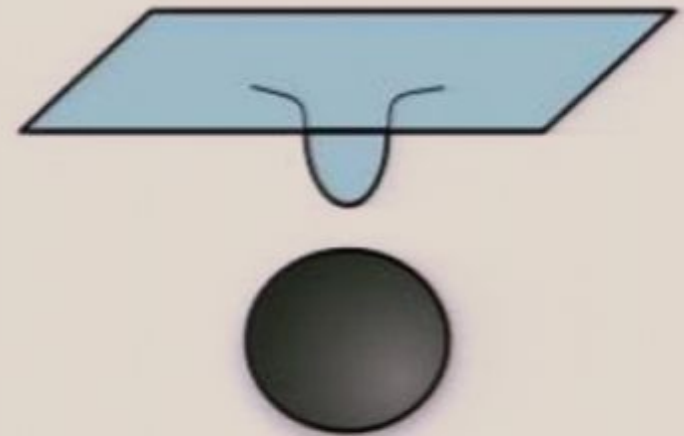
Minkowski embedding	Critical embedding	Black hole embedding
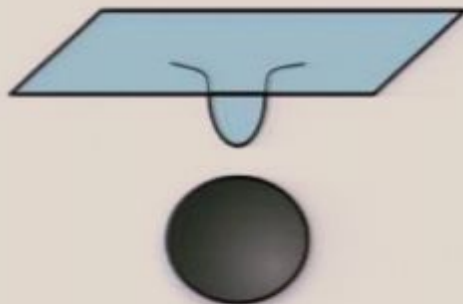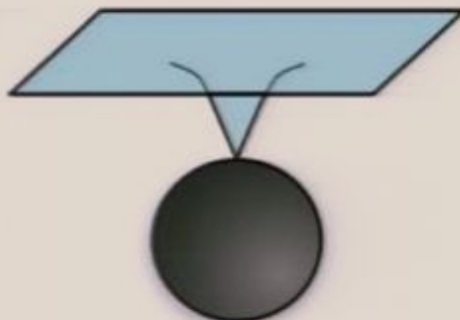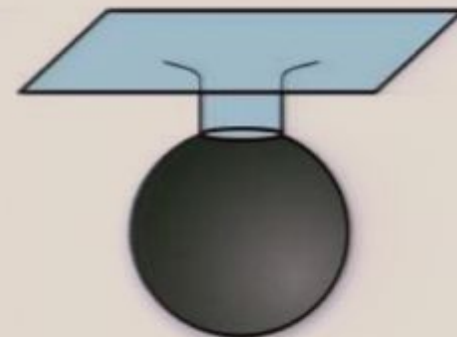
Dispersion relation

Mateos, Myers and Thomson

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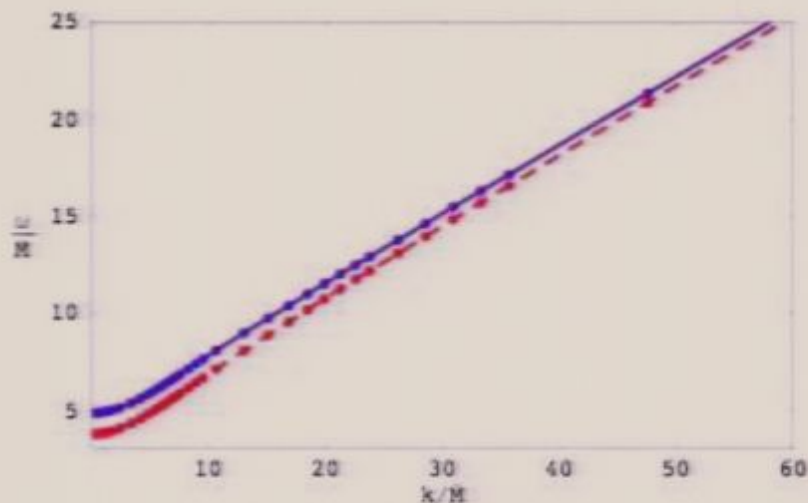
$$\omega = v_C k, \quad k \to \infty$$

$$v_C = 0.35 \quad \text{for} \quad T = 0.98 \, T_d$$

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Dispersion relation

Mateos, Myers and Thomson

Is there a **velocity bound** for mesons?

We are interested in the behavior of mesons in the **large k limit.**
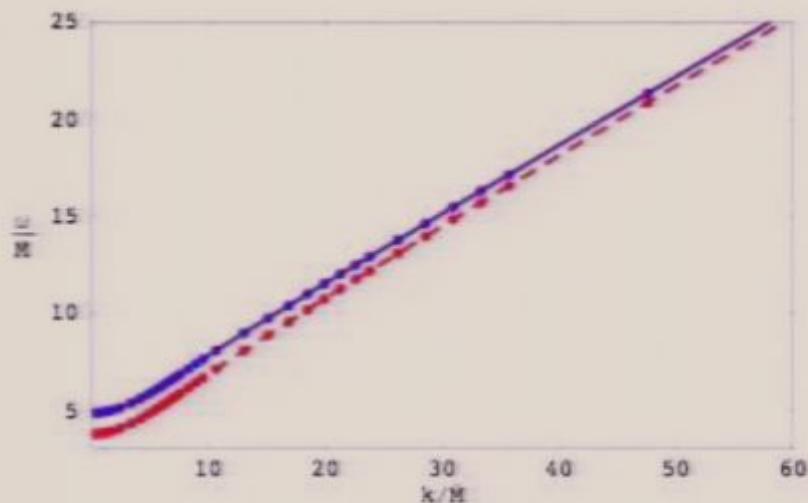
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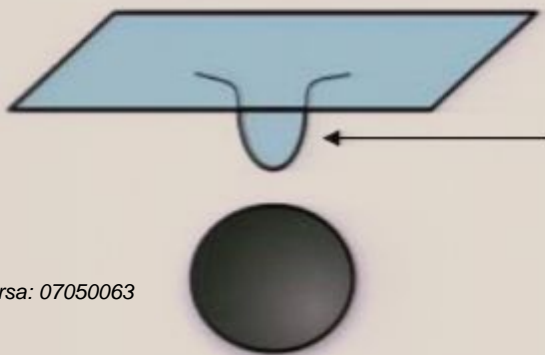
V_C: speed of light at the tip

Consistent with earlier result obtained in the regime

$$m_q \gg \sqrt{\lambda T}$$

General results ($T < T_d$)

Ejaz, Faulkner, HL, Rajagopal, Wiedemann

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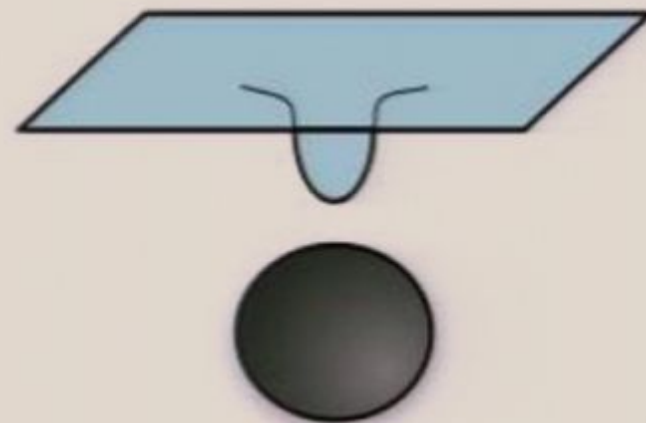
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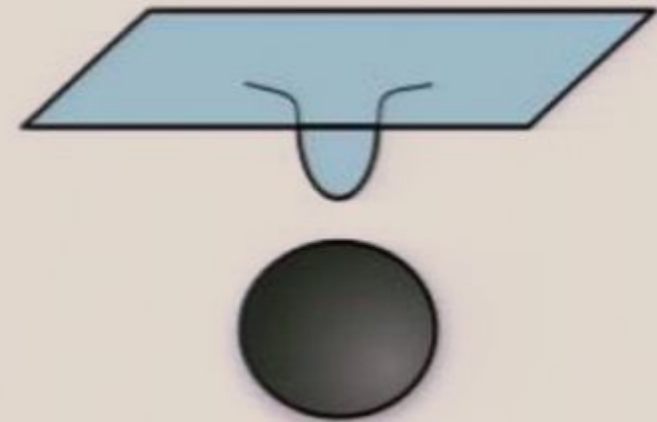
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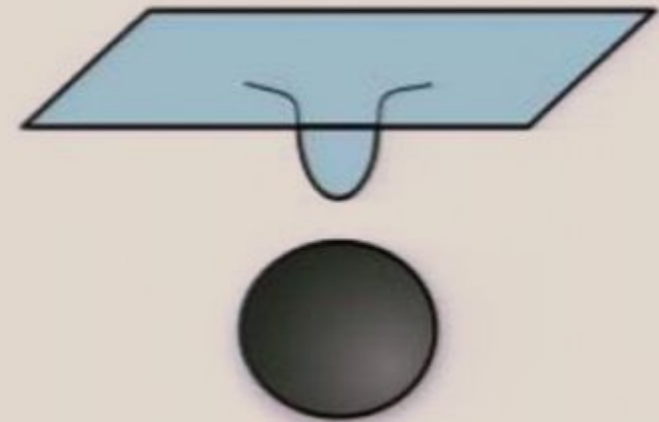
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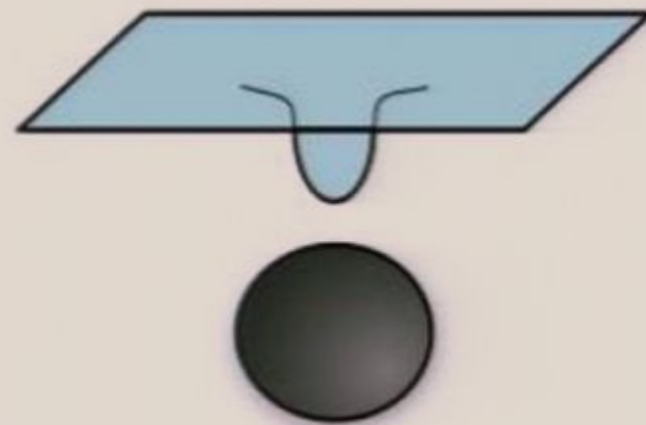
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Small T limit agrees exactly with earlier results based on classical string.

Speed limit at a generic temperature
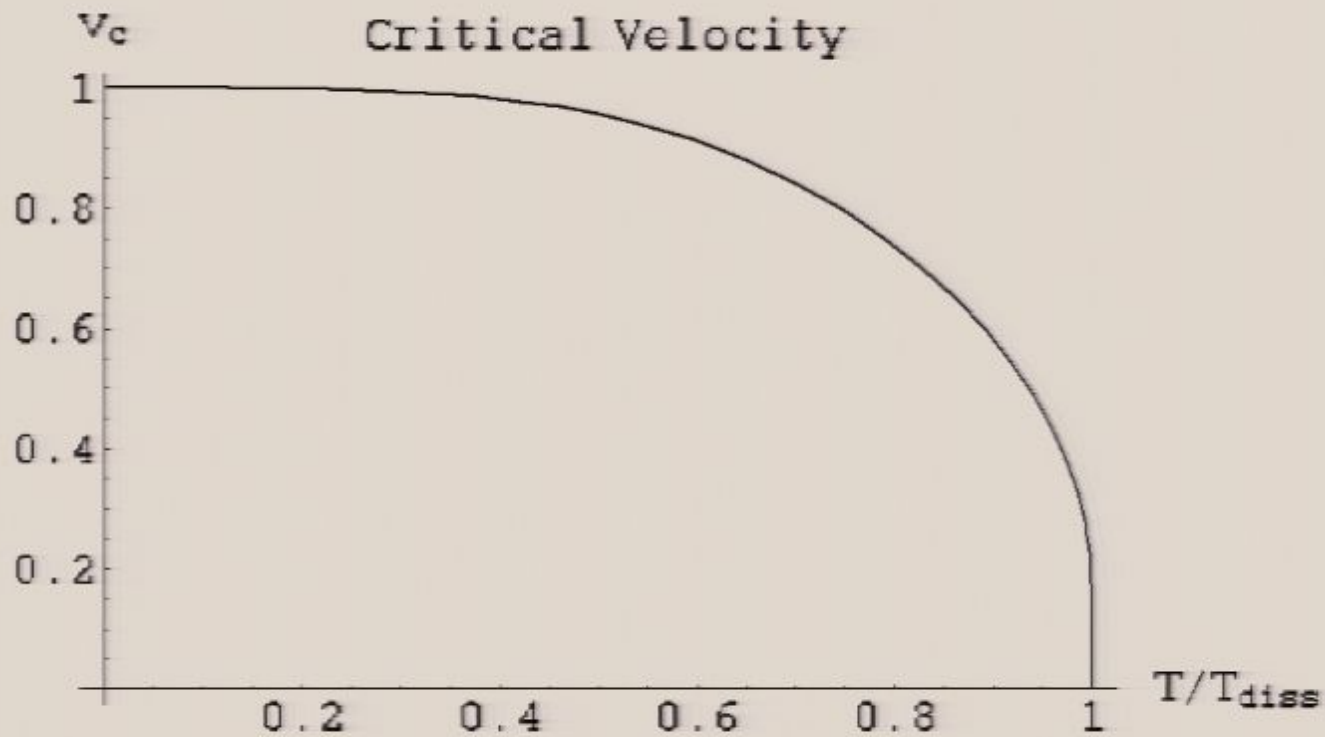
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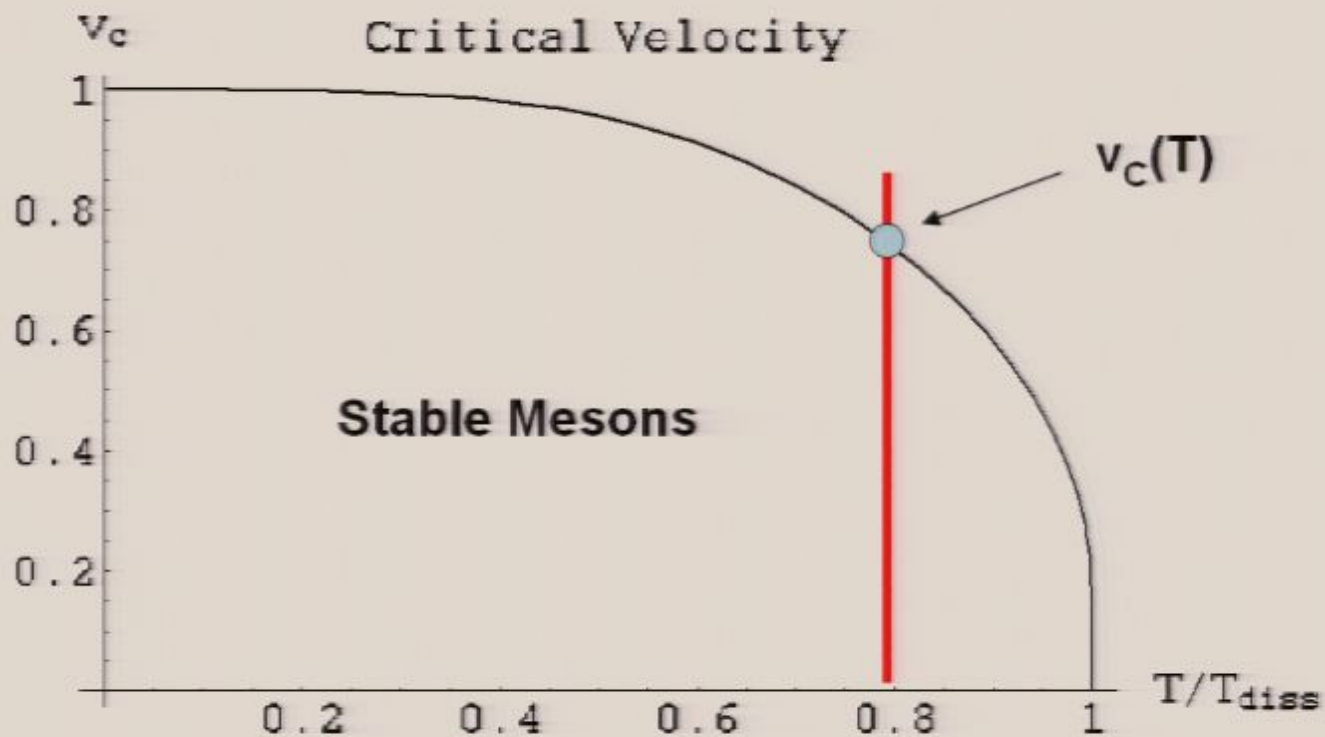
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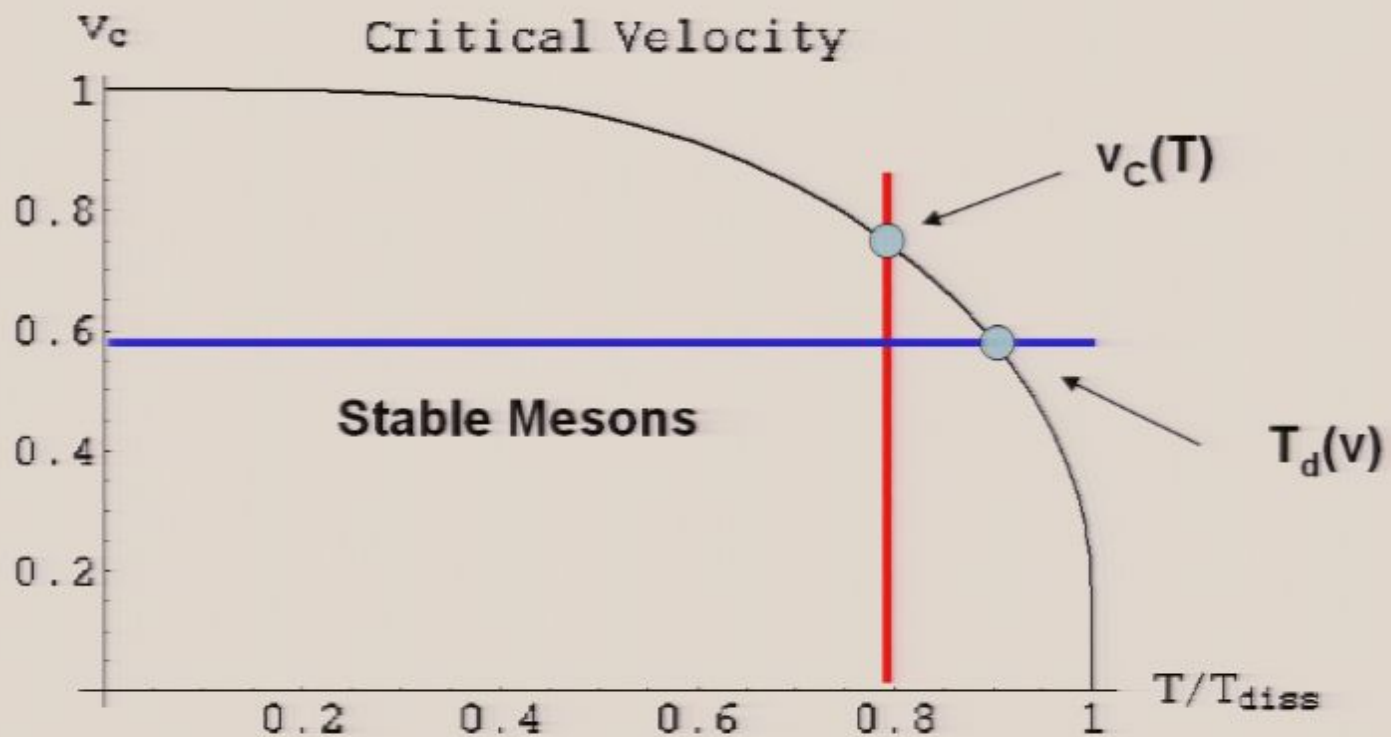
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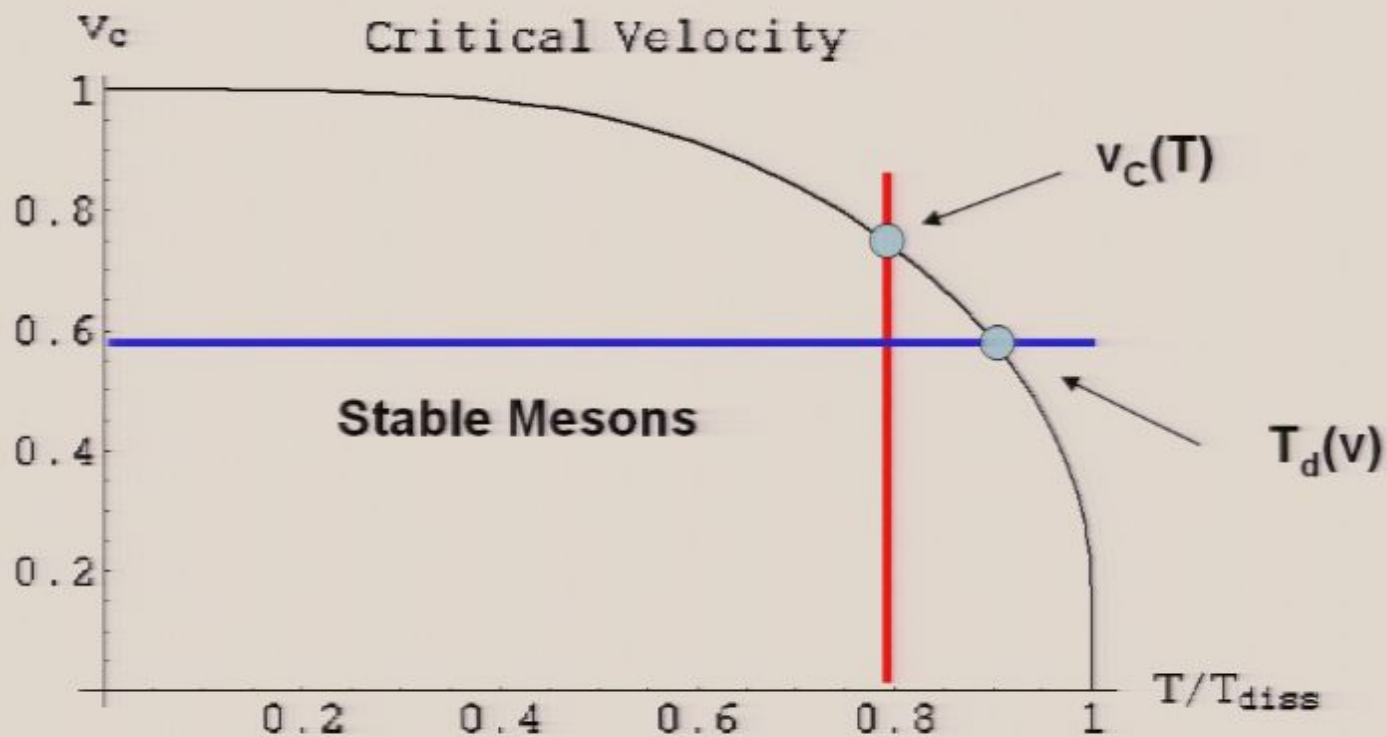
Near T_d, $v_C(T) \to 0$, for arbitrary large k.
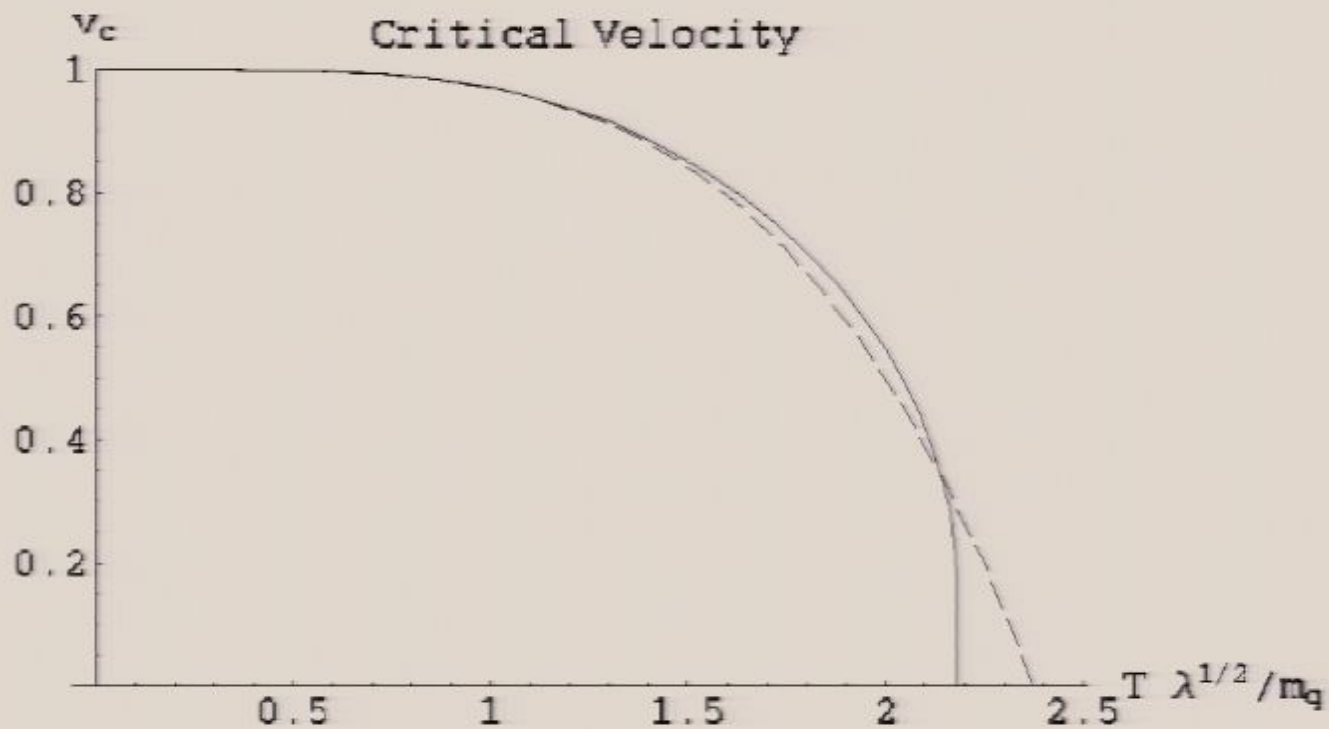
A numerical fit

$$v_c \approx 1 - \frac{2}{(1.30)^4}\left(\frac{T}{T_{diss}}\right)^4$$

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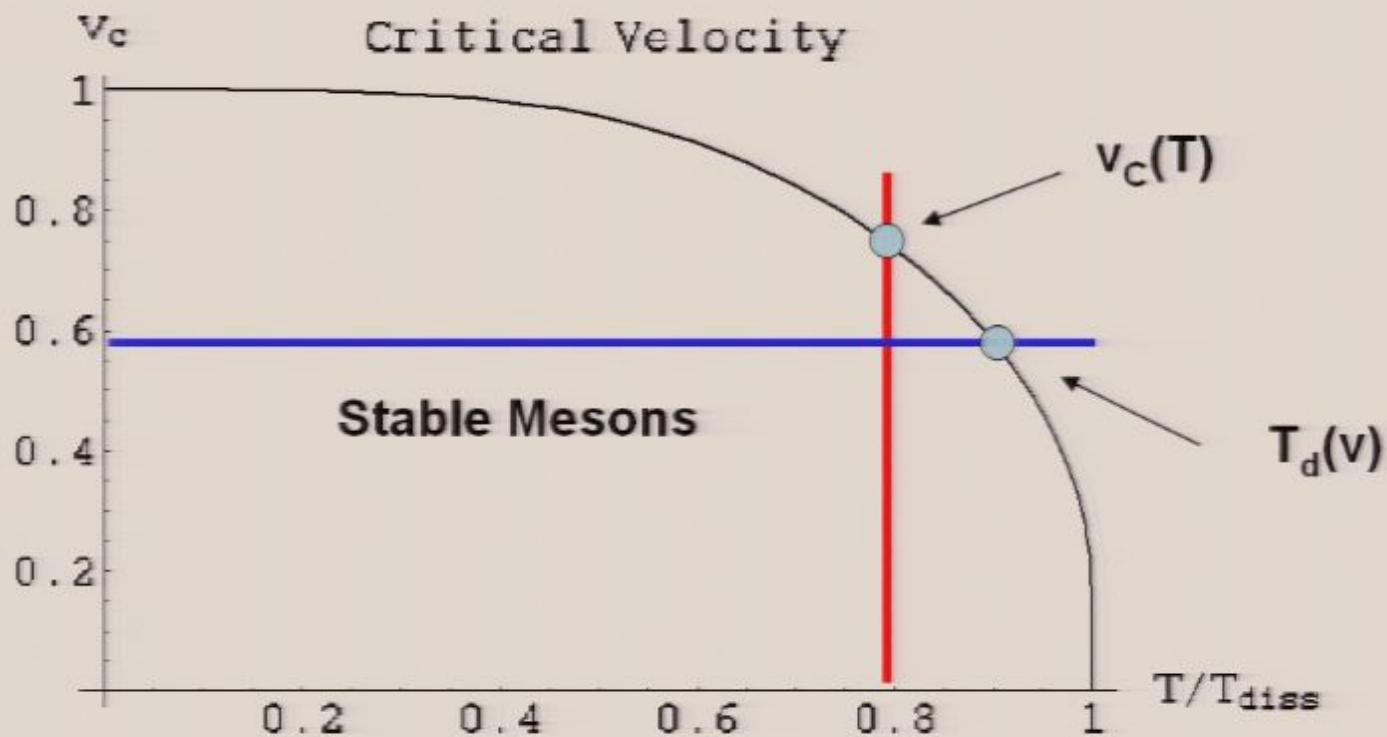
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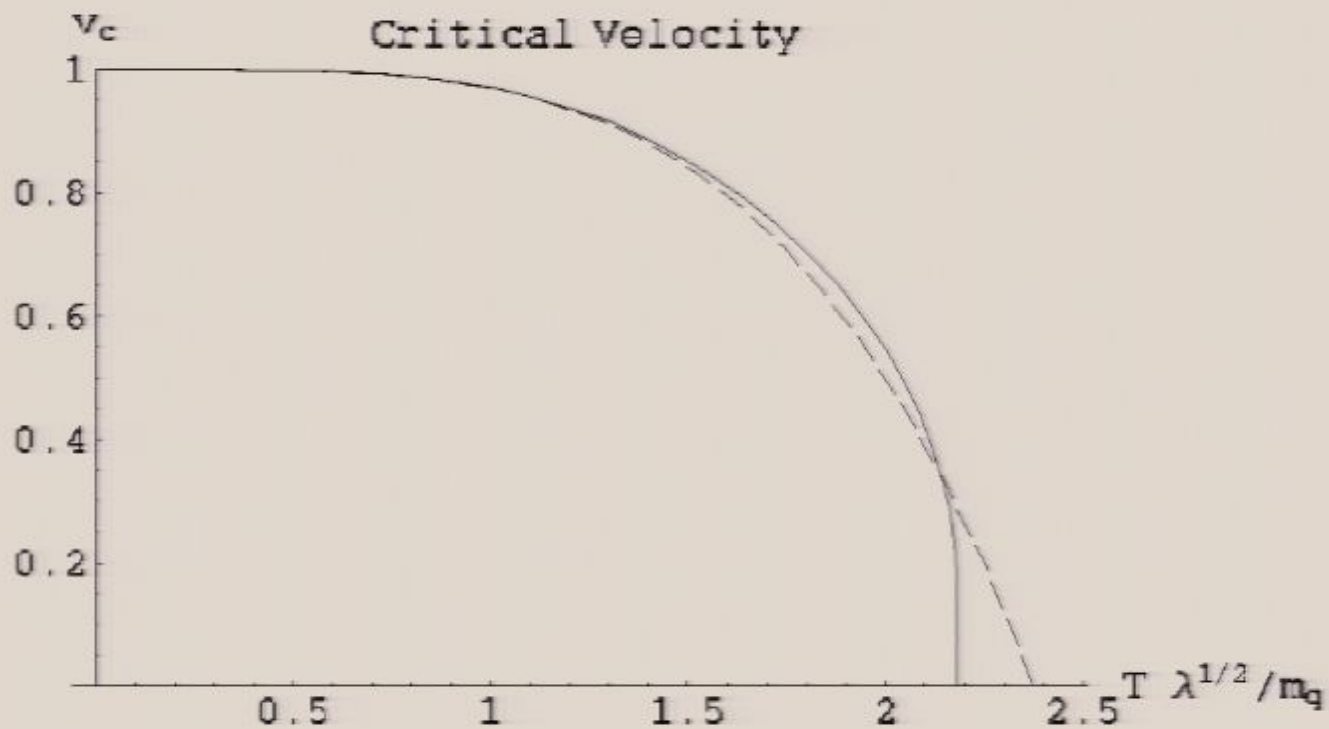
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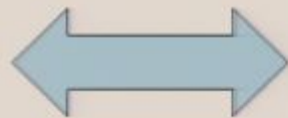
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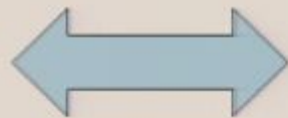
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Dramatic slowdown near T_d

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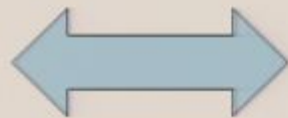
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All of them are rather qualitative features, which may not depend on the precise details of the underlying theory.

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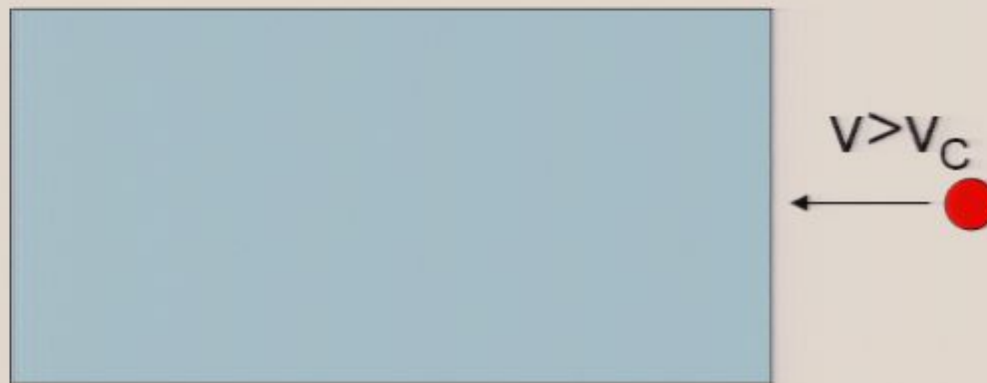

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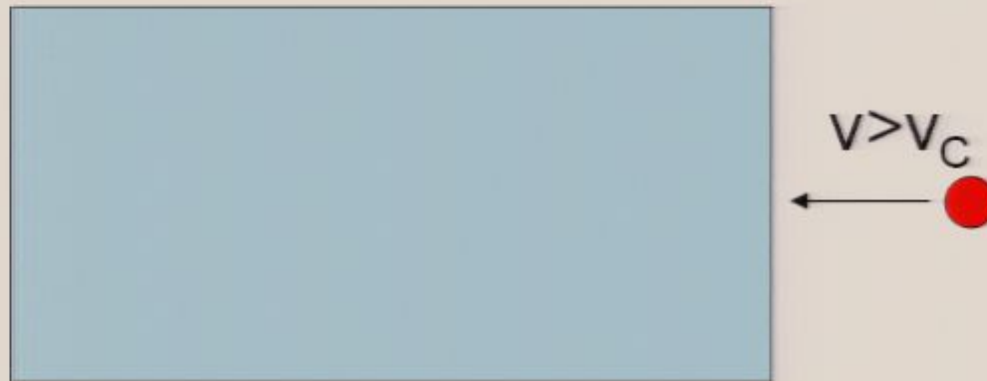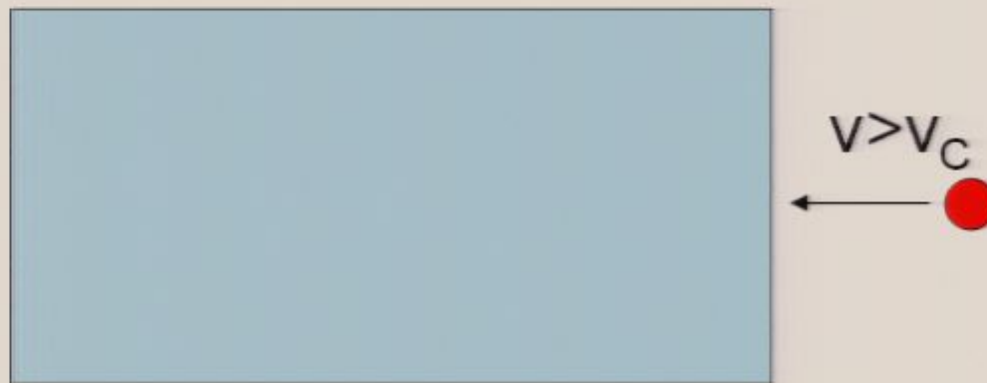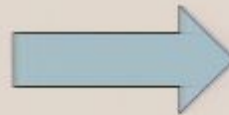
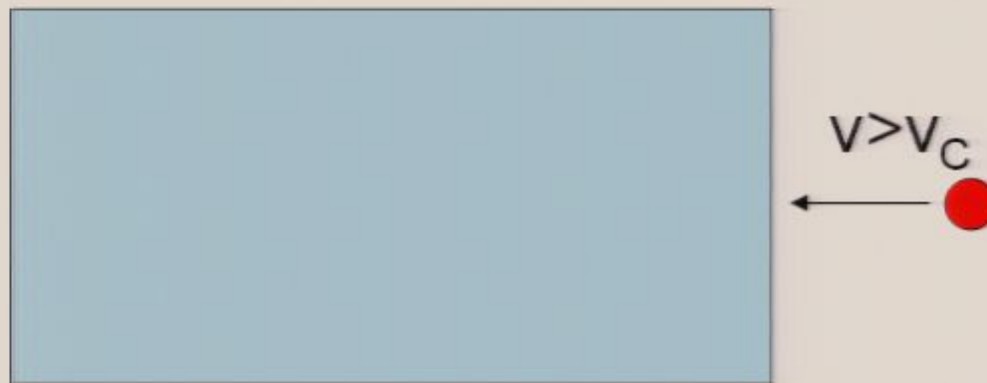Will J/ψ break apart? → J/ψ suppression

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Will J/ψ break apart?   →   J/ψ suppression

Or will it slow down and survive the medium

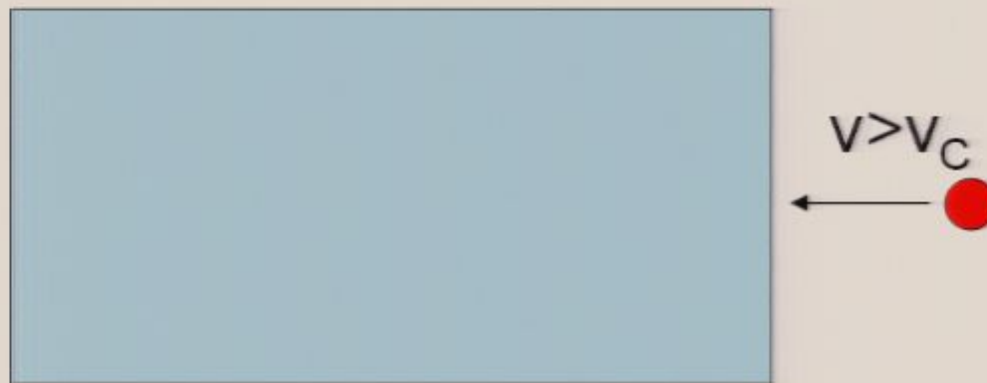# Is the modified dispersion relation observable?

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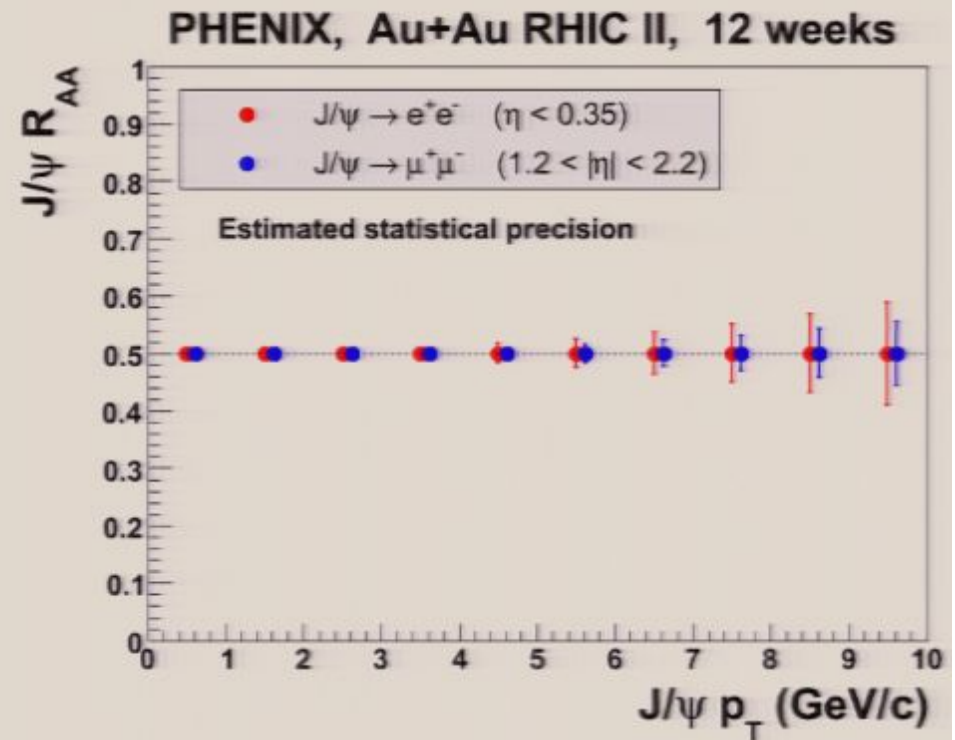
Time delay?

Data to come
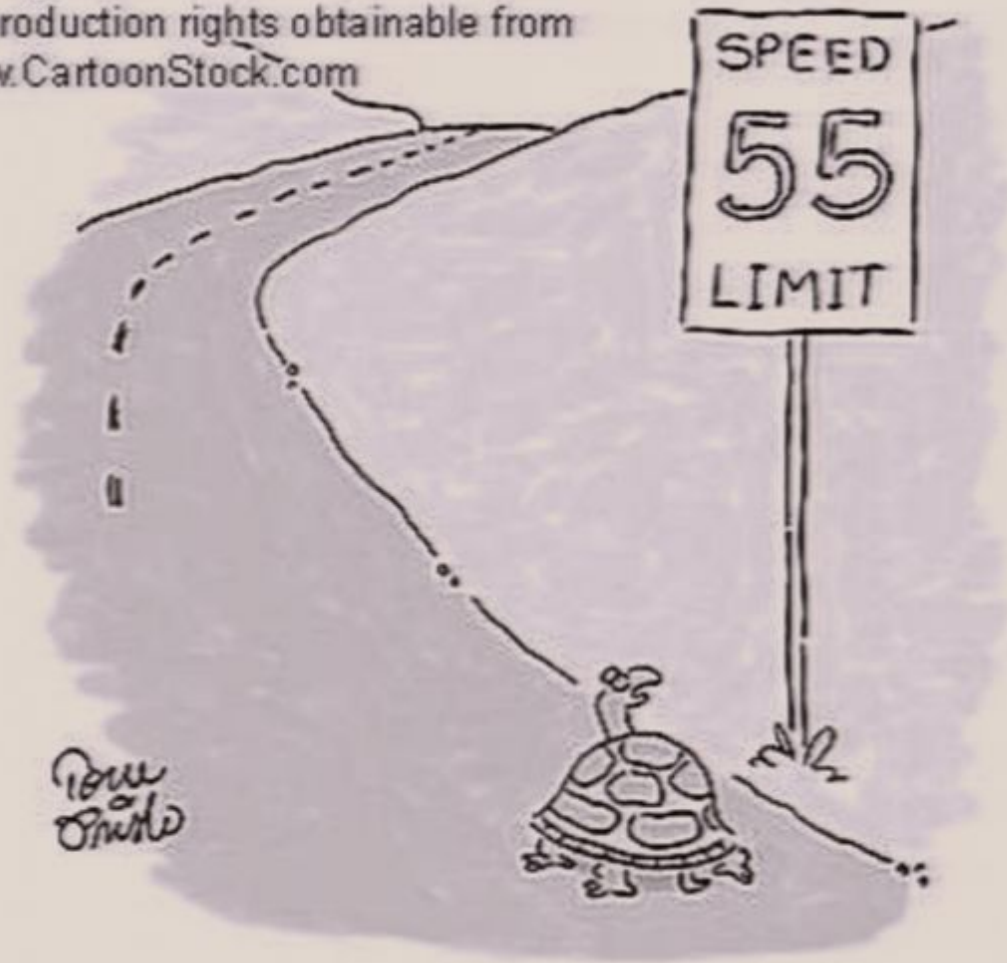
RHIC: low statistics on J/ψ with $2 < P_T < 5$ GeV, no data for $P_T > 5$GeV

Reach in P_T will extend to 10 GeV in coming years at RHIC.

LHC will reach even wider range.

PHENIX, Au+Au RHIC II, 12 weeks

J/ψ R_{AA}

- J/ψ → e^+e^- ($\eta < 0.35$)
- J/ψ → $\mu^+\mu^-$ ($1.2 < |\eta| < 2.2$)

Estimated statistical precision

J/ψ p_T (GeV/c)

"I don't think I can do it, but I'll try."
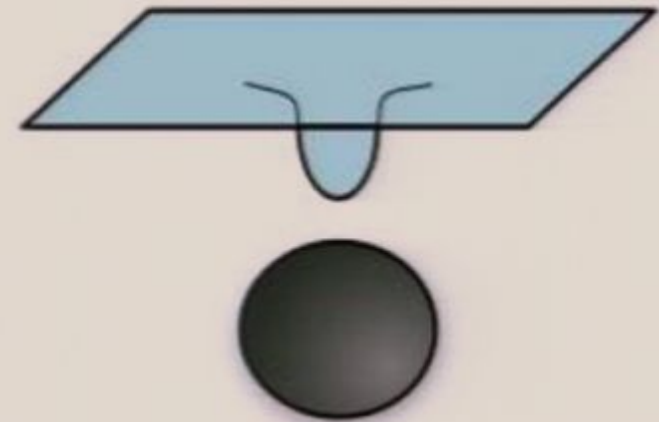
$$\frac{Mq}{\sqrt{x}} \sim T$$

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