Something Old
Something New …

Mannque Rho

Saclay

HIM 2005

The Topics

QCD in action

- EFT vs. MEEFT for Nuclear Physics
- The “Origin” of Hadron Masses
- Personal Musing …

EFT vs. MEEFT

- SNPA : Something old

Construct "accurate" nuclear potentials (two-body as well as well as many-body) and solve *exactly* LS or S equations. Works up to A~10 with an accuracy of ~ 99%. But caveat: Unpredictive and don't know how to improve AND what does SNPA have to do with QCD??

- EFT : Something new

Weinberg "folk theorem" (79) ⟶ Erice Lecture (81) ⟶ Weinberg counting (91) ⟶ Two schools (96)

"Theorem"

S. Weinberg, "What is quantum field theory and what did we think it is?" hep-th/9702027

This leads us to the idea of effective field theories. When you use quantum field theory to study low-energy phenomena, then according to the folk theorem you're not really making any assumption that could be wrong, unless of course Lorentz invariance or quantum mechanics or cluster decomposition is wrong, provided you don't say specifically what the Lagrangian is. As long as you let it be the most general possible Lagrangian consistent with the symmetries of the theory, you're simply writing down the most general theory you could possibly write down. This point of view has been used in the last fifteen years or so to justify the use of effective field theories, not just in the tree approximation where they had been used for some time earlier, but also including loop diagrams. Effective field theory was first used in this way to calculate processes involving soft π mesons,[12] that is, π mesons with energy less than about $2\pi F_\pi \approx 1200$ MeV. The use of effective quantum field theories has been extended more recently to nuclear physics,[13] wher although nucleons are not soft they never get far from their mass shell, an for that reason can be also treated by similar methods as the soft pion Nuclear physicists have adopted this point of view, and I gather that the are happy about using this new language because it allows one to show in fairly convincing way that what they've been doing all along (using two-bod potentials only, including one-pion exchange and a hard core) is the corre first step in a consistent approximation scheme. The effective field theor

Two schools

1. Seattle gang ("Axiomatic EFTers"):
   (a) Weinberg counting is wrong, (b) for a consistent EFT, integrate out everything other than the nucleons, the pions and hence chiral symmetry play no special role etc …
   (c) Sum infinite Feynman diagrams with the nucleons-only contact interactions in a given regularization scheme called "PDS

Therefore

Yukawa idea for nuclear force is dead, wave functions have no physics in them. Nuclear physicists have been doing wrong physics. Throw SNPA into the wastebasket….

Helas … but to no great surprise …

Torpedoed by tensor force** from pion exchange!!! Cannot even go beyond old effective range theory.

Moot for A > 3.

** Well known since ages to be very important in nuclear physics …

Thus spake George Santayana …

2. Korean gang ("Pragmatic EFTers": T.-S. Park, D.-P. Min, MR, G.E. Brown, K. Kubodera …): Marry the old (SNPA) and the new (EFT) a la Weinberg (and also Wilson). Perhaps not 99.9% accurate but highly predictive even for A= 4 ~ 209 ~ 10^{57}.

e.g., solar *hep* process, laboratory *hen* process, … axial charge in heavy nuclei ….

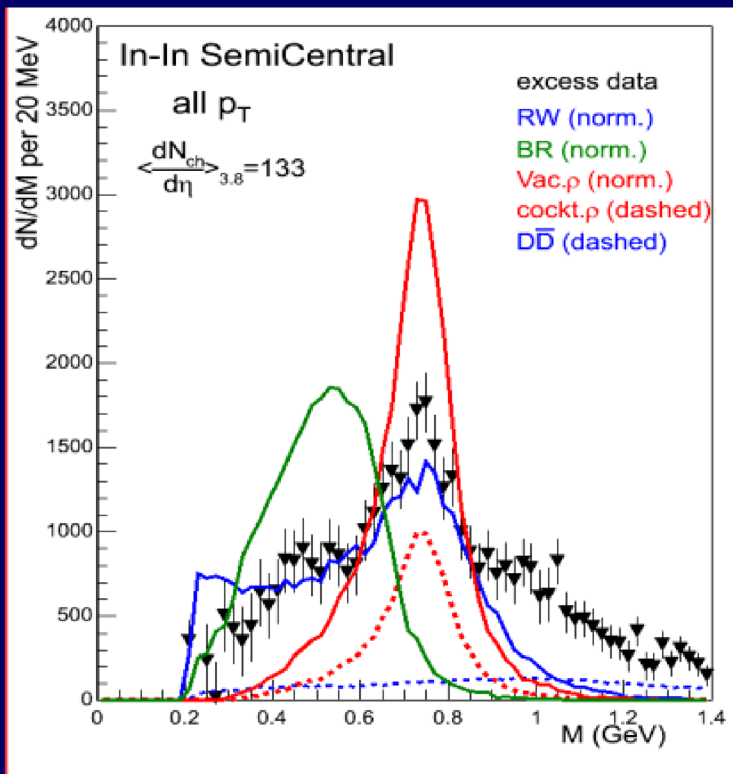
(Young-Ho Song's thesis)

Weinberg theorem vindicated!

The "Origin" of Hadron Masses

NA60
QM 2005

Comparison of data to RW, BR and Vacuum ρ



Predictions for In-In by Rapp et al (2003) for □$dN_{ch}/d\eta$□ = 140, covering all scenarios

Theoretical yields, folded with acceptance of NA60 and normalized to data in mass interval < 0.9 GeV

Only broadening of ρ (RW) observed, no mass shift (BR)

"BR Ruled out!"

What can one say?

- It’s a beautiful experiment after ~ a decade of hard and careful work!
- What’s in it? Not so fast and think more … before giving a physical interpretation of the result.

Issue: Where do Hadrons get their masses?

- Standard lore: chiral symmetry is "spontaneously broken" (χSB) and the pion is a (pseudo-)Goldstone boson
- Current quark masses in QCD Lagrangian are tiny for the hadrons, e.g., proton, …
- So, ~ 99% of the hadron mass (other than that of the pion) must be coming from χSB
- Experiment: Restore chiral symmetry and observe the "melting" of the mass

What do we have?

- 1. “Garbage” is not fully cleaned up, so we have a mess. We can say nothing.
- 2. The experiment is not probing the right kinematics where the mass shift should be visible.
- 3. The kinematics is OK and the garbage is completely cleaned up and we see the meson mass unshifted with its width simply blown up.
- 4. What’s happening is a lot subtler than we think and what we observe is not what we think it is.

Consequences

- If (1) and (2), then back to the drawing board for the experimentalists. Theorists will have to wait.
- If (3), a shameful waste (!!) for that experiment that cost $? Millions or, if extremely lucky, a revolutionary demonstratior that the standard lore -- overwhelmingly accepted -- is false. The latter will push theorists back to the drawing board: *Is the notion of hadron masses coming from χSB a red herring?*
- If (4), Nature is cleverer than we. Bring old to new ?

Lesson from the past

(How nature conspires and fools us …)

Isoscalar convection current for a nucleon quasiparticle moving on the Fermi surface: Naively

$\mathbf{J}=\mathbf{k}/m^*$?

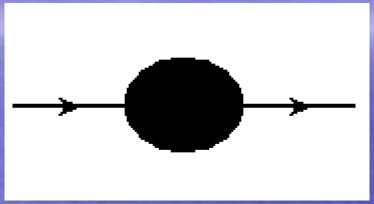
m^*= Landau effective mass
~ 0.6 m_N in nuclear matter

This is *wrong* because of "backflow" due to medium.
To get the right answer, impose Galilean invariance
(or Lorentz invariance if relativistic)

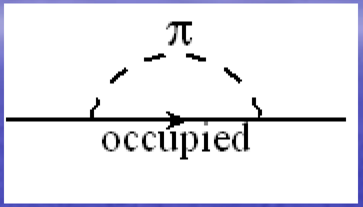
⟶ $\mathbf{J}=\mathbf{k}/m_N$ But mass does shift!

What's involved?

Δm ~



+



$G(<\bar{q}q>^*)$

χS

χSB new

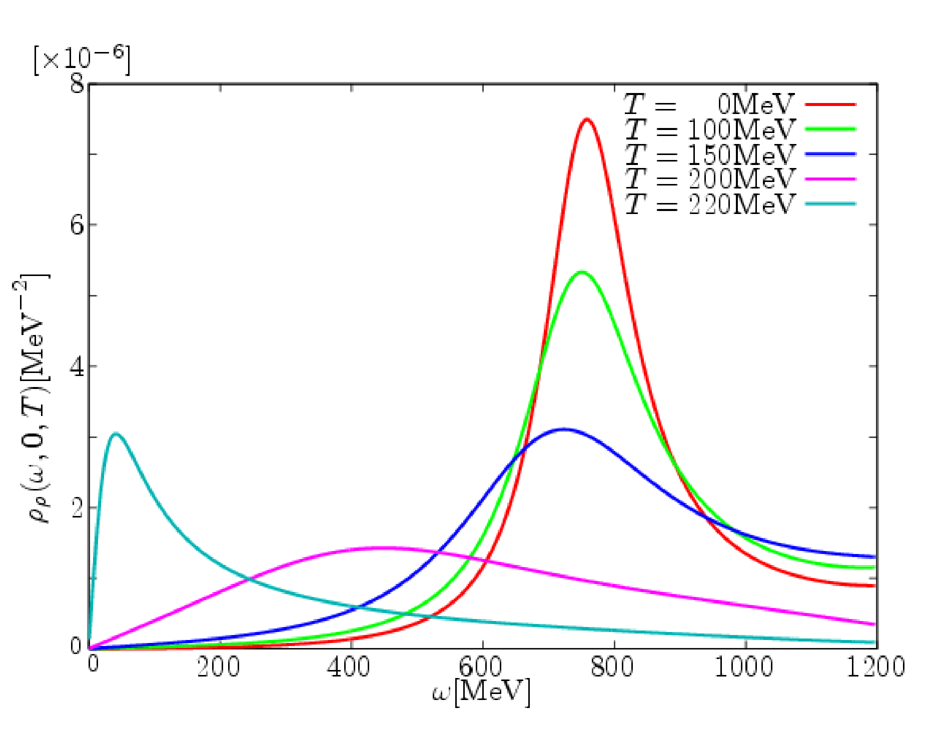
$H(\mathcal{F})$

Landau parameters: Many body interaction

old

Preliminary

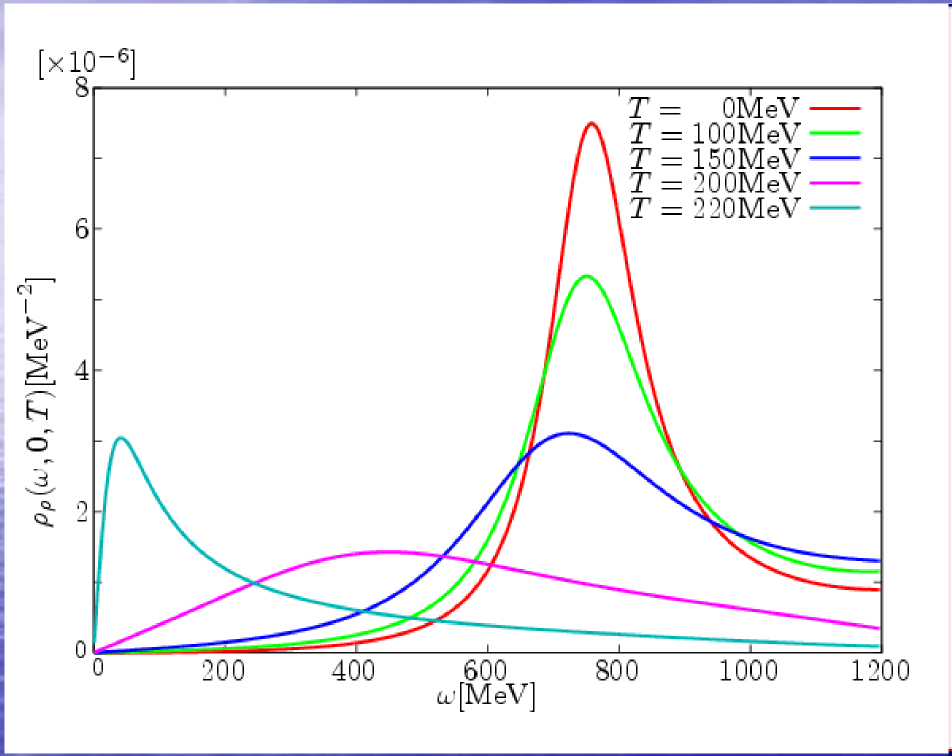
(Compliment of Morimatsu)



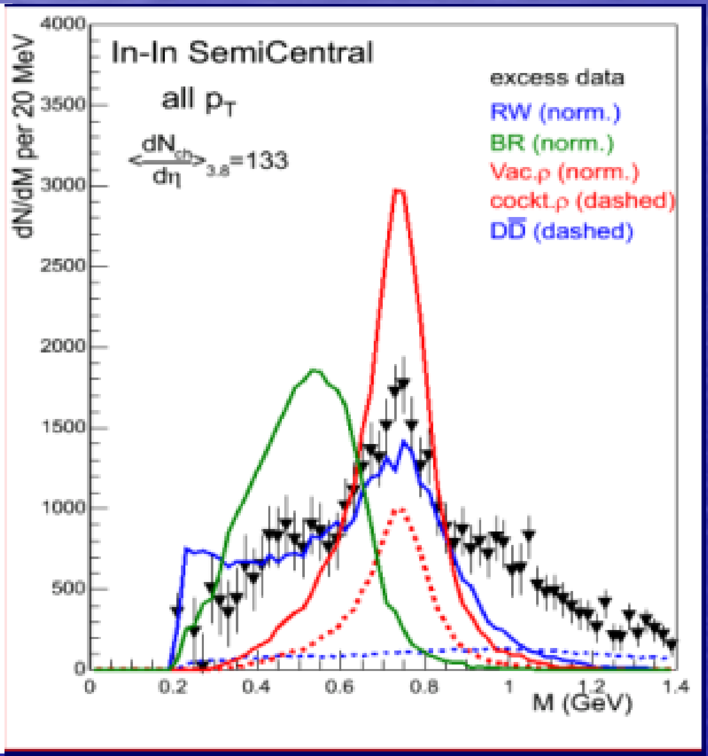
Hidden local symmetry
Implemented partly

m_ρ=0 at
T ~ 220 MeV

Compare



Morimatsu



NA60

Private Musing

- RHIC: "New Matter"

  New top down to T_c: AdS/QCD

  Old bottom up to T_c: HLS/VM

  marry

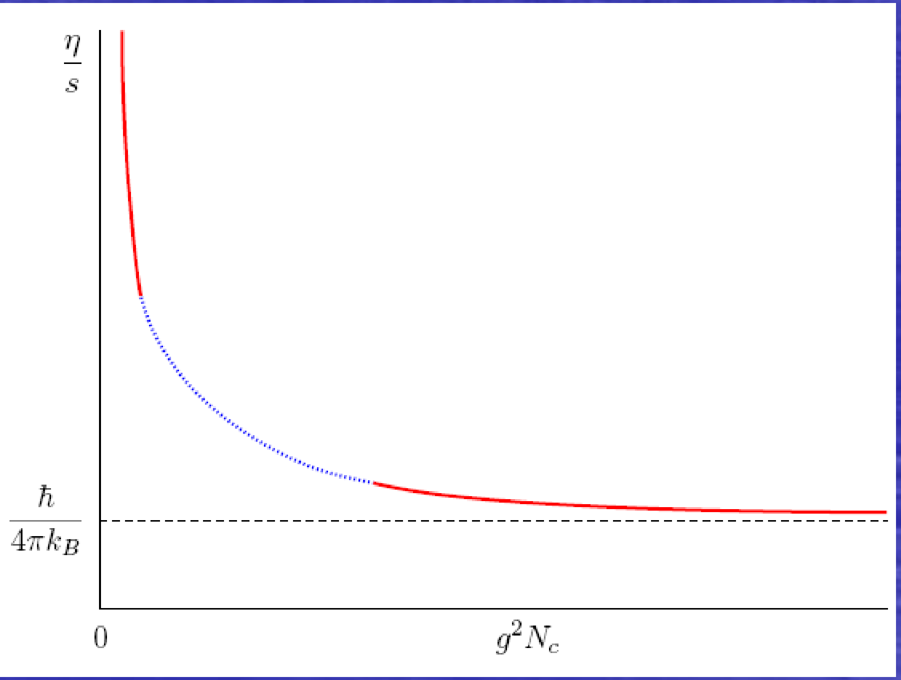
Igor Klebanov, Lepton-Photon Conf. 2005

Viscosity/entropy conjecture

- In the SYM theory at very strong coupling

$$\frac{\eta}{s} = \frac{\hbar}{4\pi k_B} \approx 6.08 \times 10^{-13}\ \mathrm{K\,s}$$

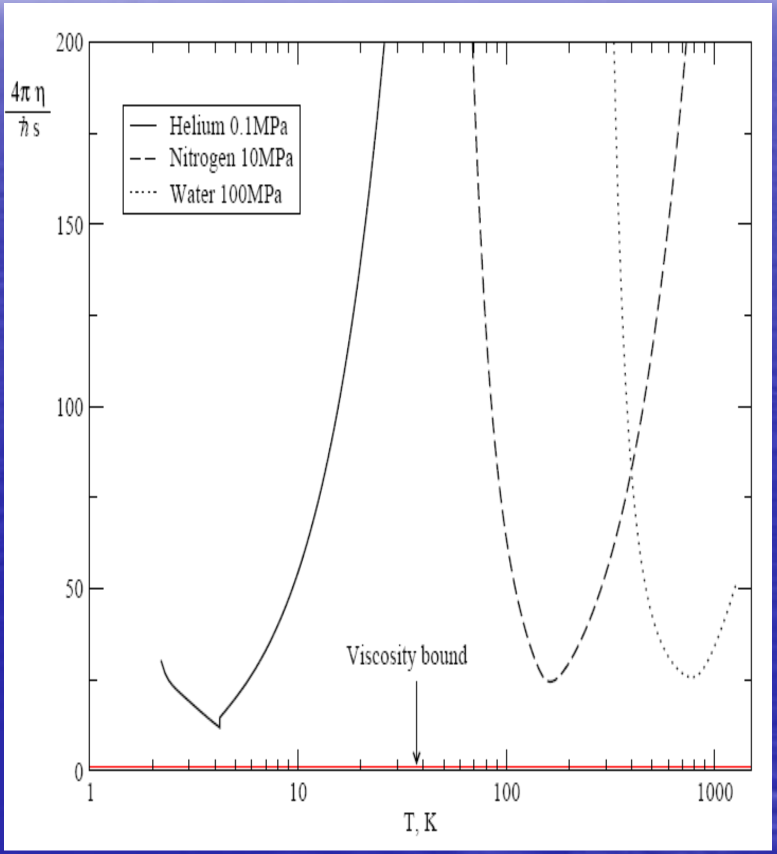
- At weak coupling this quantity is very large: it scales as mean time between collisions. There is evidence that it decreases monotonically.

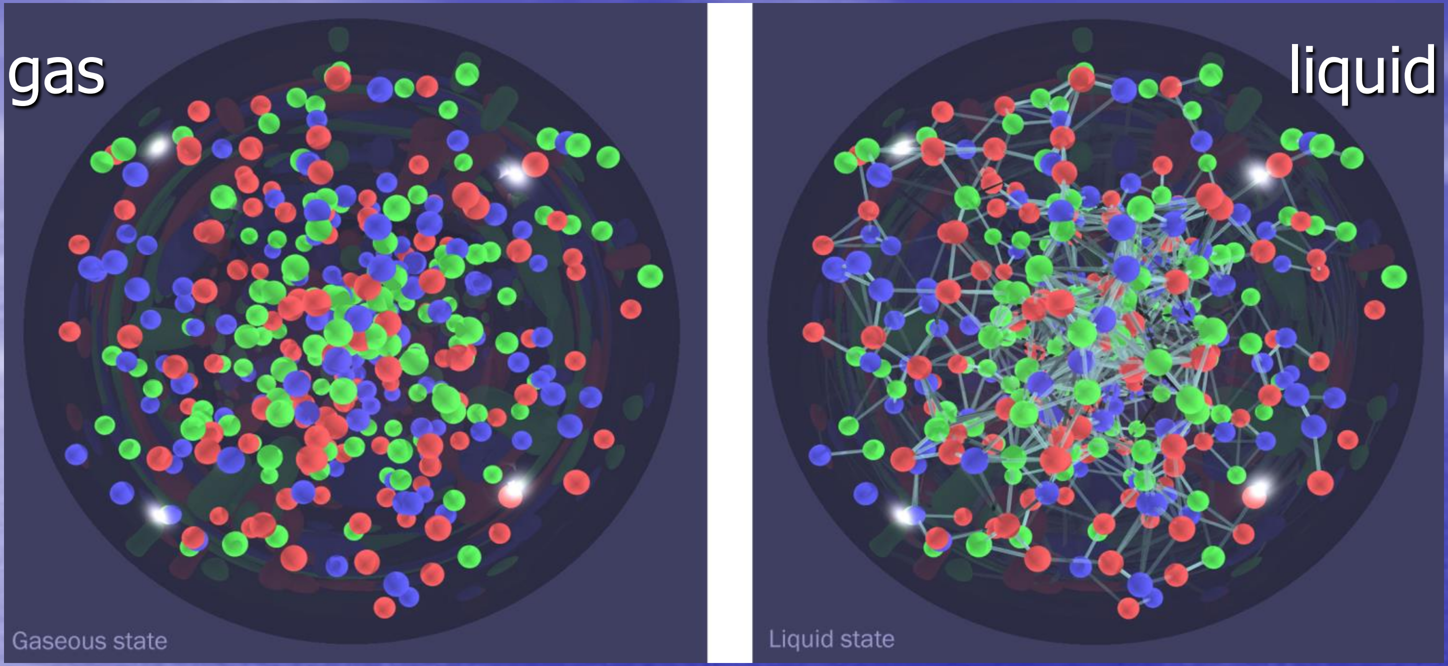


Igor Klebanov

Is very strongly coupled SYM the most perfect fluid?

- For known fluids (e.g. helium, nitrogen, water) the ratio is considerably higher.
- The quark-gluon plasma produced at RHIC is believed to be strongly coupled, and to have very low viscosity, which is yet to be measured precisely.





"The truly stunning finding at RHIC that the new state of matter created in the collisions of gold ions is more like a liquid than a gas gives us a profound insight into the earliest moments of the universe," said Dr. Raymond L. Orbach, Director of the DOE Office of Science. "The possibility of a connection between string theory and RHIC collisions is unexpected and exhilarating. String theory seeks to unify the two great intellectual achievements of twentieth-century physics, general relativity and quantum mechanics, and it may well have a profound impact on the physics of the twenty-first century." (from a BNL press release, April 2005)

- HIM: Which way to go?