フォトンの光と陰

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@ HIP 1st meeting

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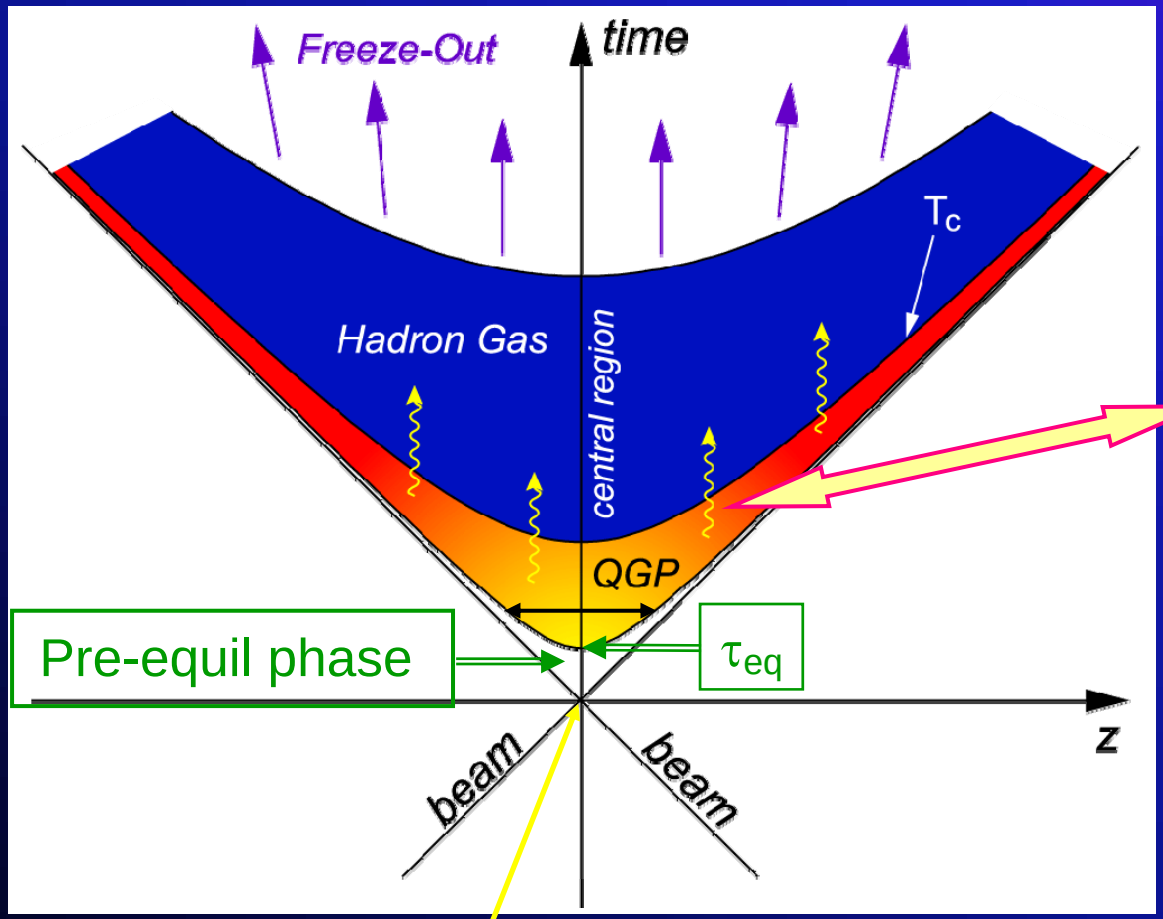
What can be observed?

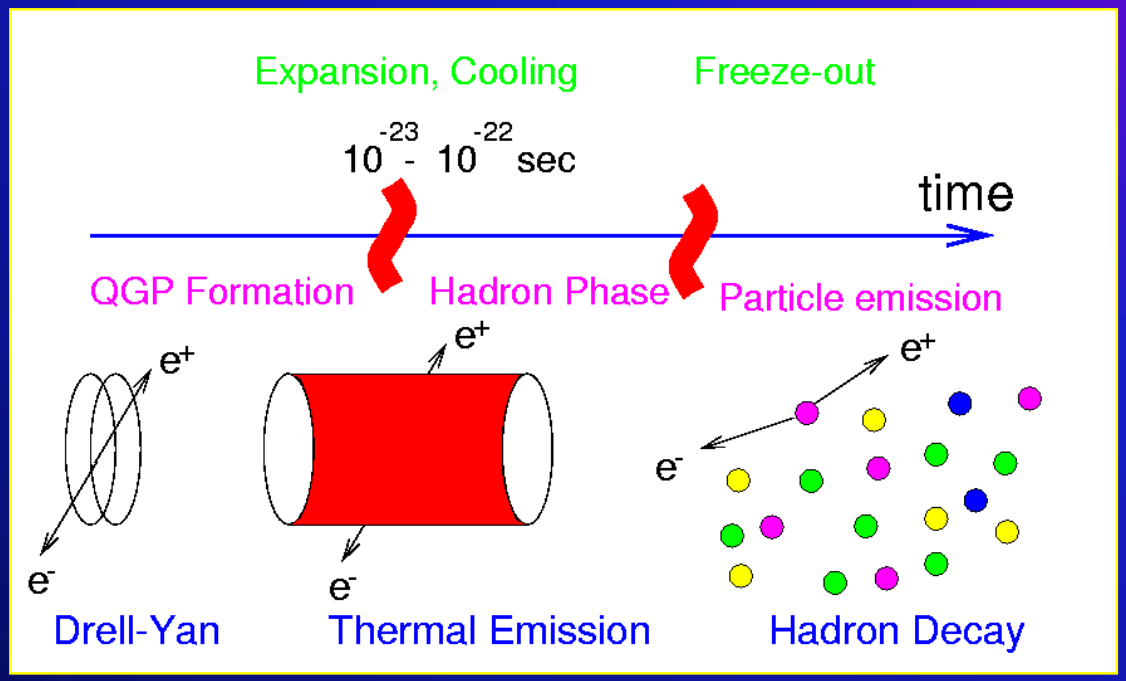


Exception is EM probes (dileptons, photons)

Mean free path of photons, leptons
$\sim\mathcal{O}(1/\alpha)$ fm

Liberation of saturated low-x glue fields

Hadrons & Leptons/Photons



Leptons, Photons —— interact only weakly (e.m.)

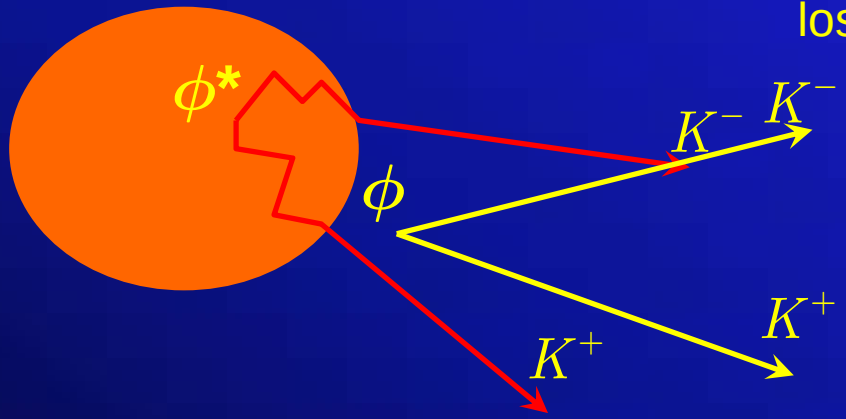
thus, *carry information of hadron/QGP phases*

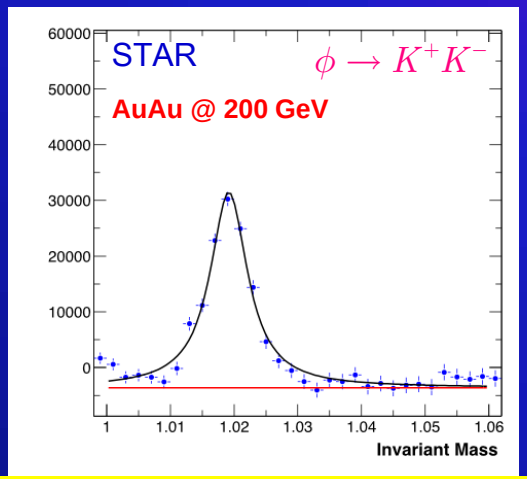
Hadrons —— strong interaction

thus, *only info of hadron phase (with some exceptions)*

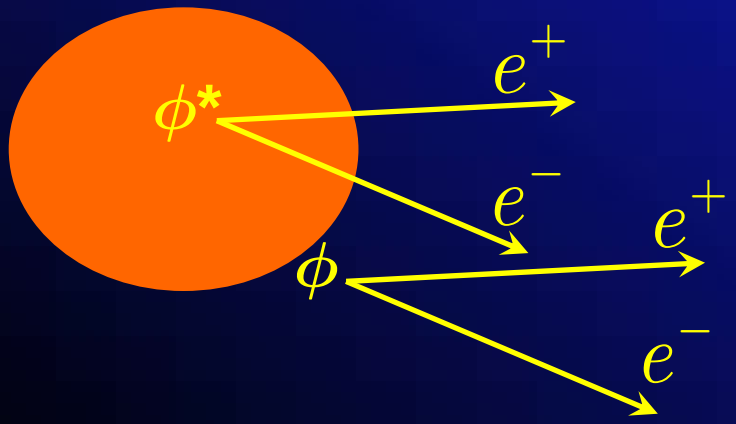
Comparison of Hadrons and Leptons

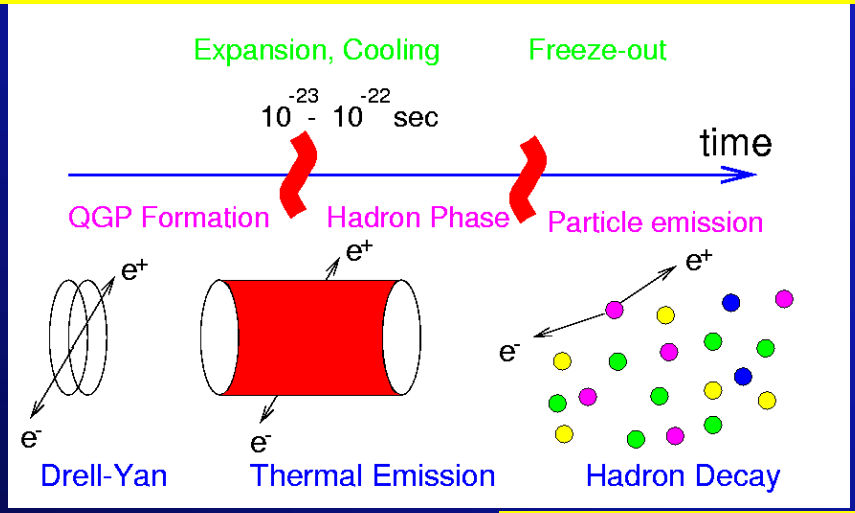
- Most of K^+K^- from in-medium decay of ϕ lose their initial momentum information





Even experts do not recognize this...





Then, what photons/leptons are interesting?

- Examples

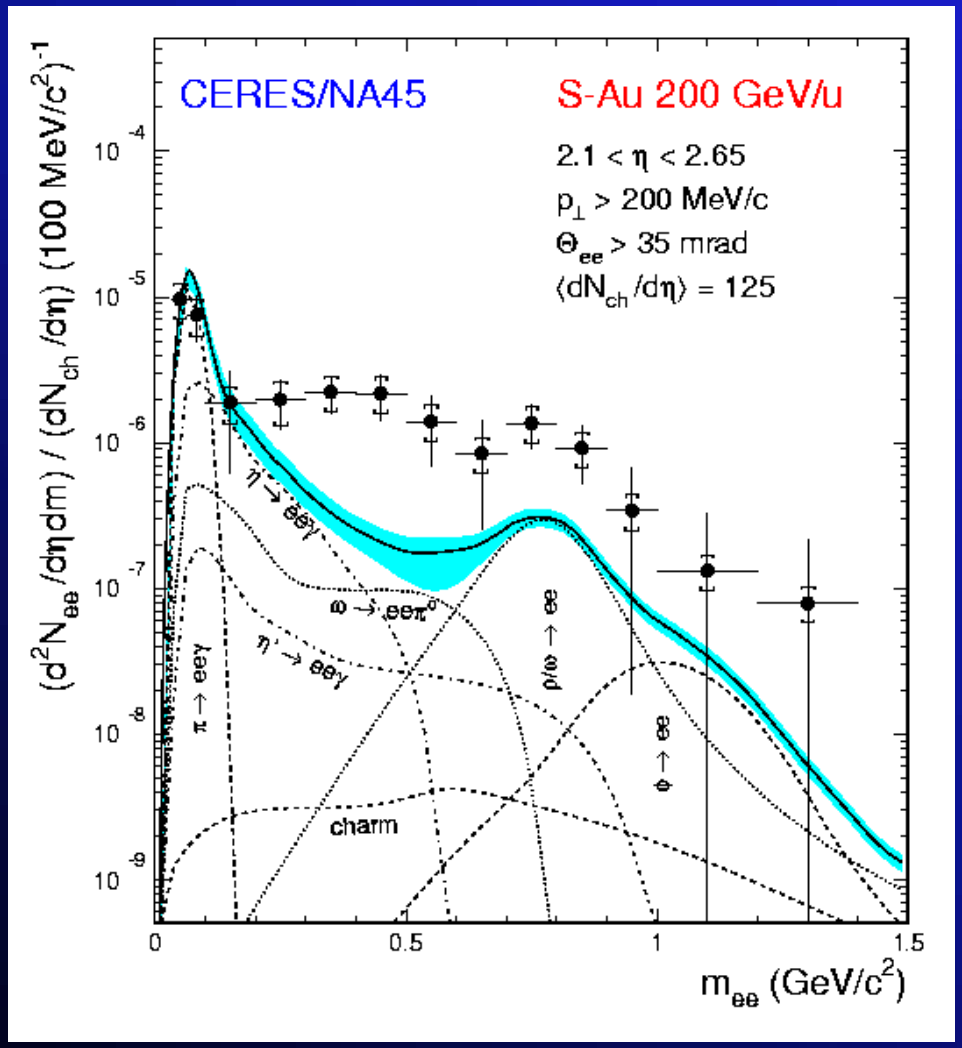
$\pi^0 \rightarrow 2\gamma$ important in jet physics, but not directly related to QGP

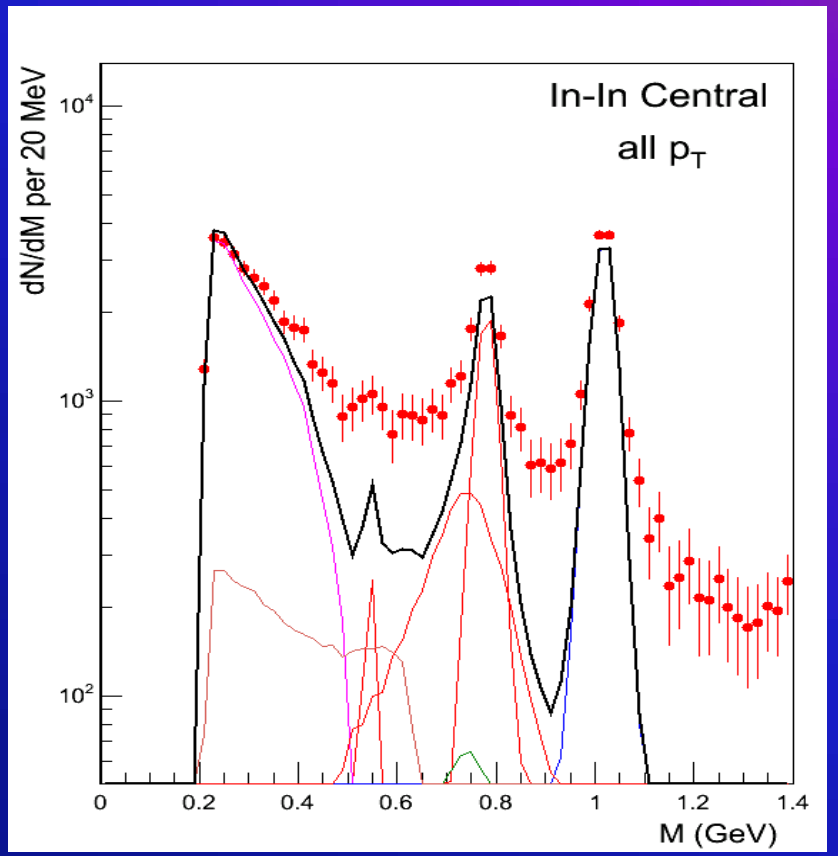
$J/\psi \rightarrow e^+e^-$ negligible contribution from hot phase

$K^* \rightarrow K\gamma$ maybe, non-negligible contribution from hot phase, but K is subject to rescattering

$\rho \rightarrow e^+e^-$ much in-medium contribution is expected

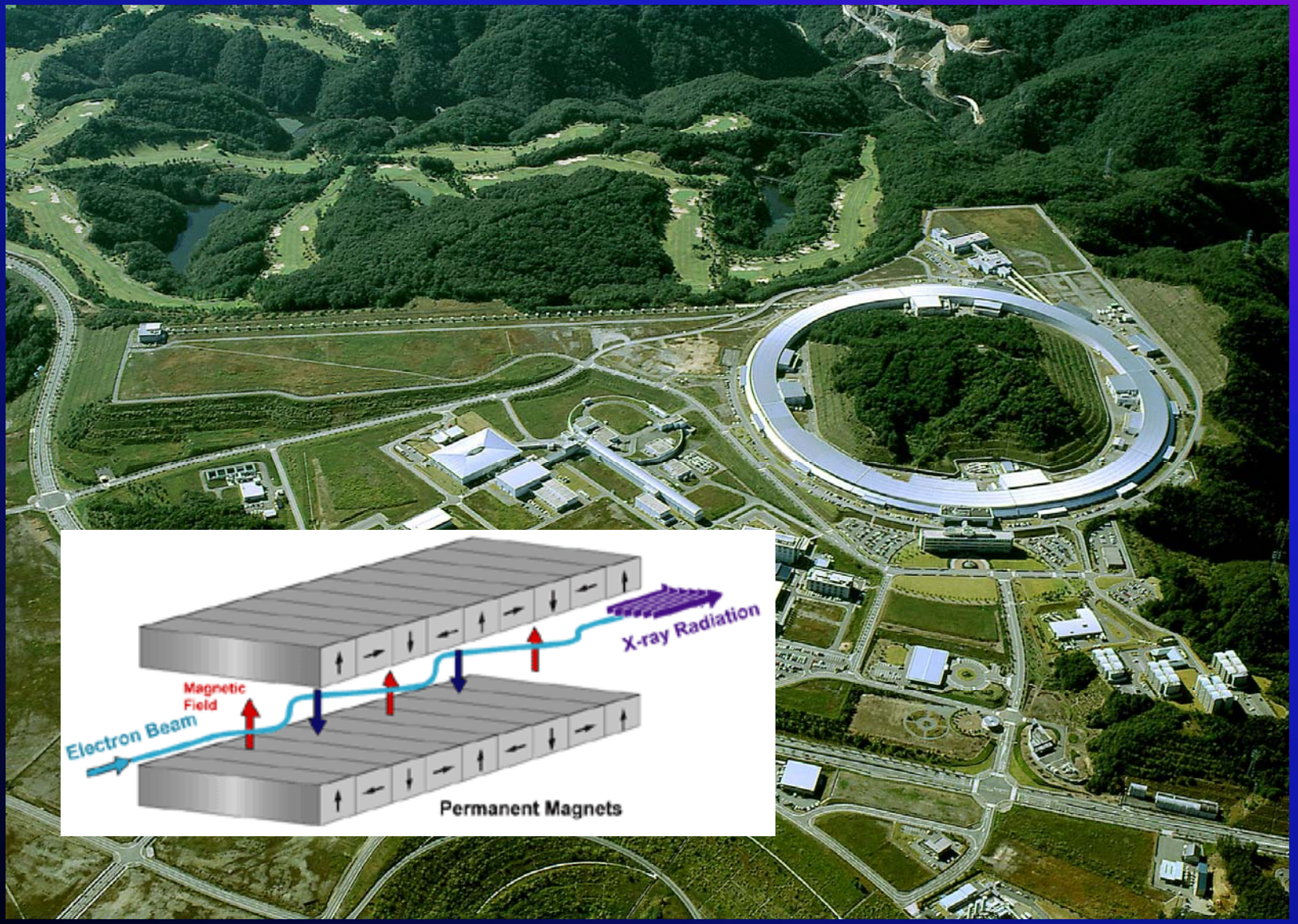
Vacuum vs. In-medium Contributions





more recent data by NA60

Photon Production in QGP: Bremsstrahlung



Photon and Dilepton production rates

- Photon production rate

$$\omega \frac{d^3 R_\gamma}{d^3 p} = \frac{\alpha}{\pi} \frac{\rho_T(\omega = |\vec{p}|, \vec{p})}{\exp(\omega/T) - 1}$$

- Dilepton production rate

$$\frac{d^4 R_{l^+l^-}}{d^4 p} = \frac{\alpha^2}{3\pi^2 p^2} \frac{(2\rho_T + \rho_L)(\omega, \vec{p})}{\exp(\omega/T) - 1}$$

(for massless leptons)

where ρ_T and ρ_L are given by

$$\rho_{\mu\nu}(\omega, \vec{p}) = \rho_T(\omega, \vec{p})(P_T)_{\mu\nu} + \rho_L(\omega, \vec{p})(P_L)_{\mu\nu}$$

$\rho_{\mu\nu}$: QCD EM current spectral function

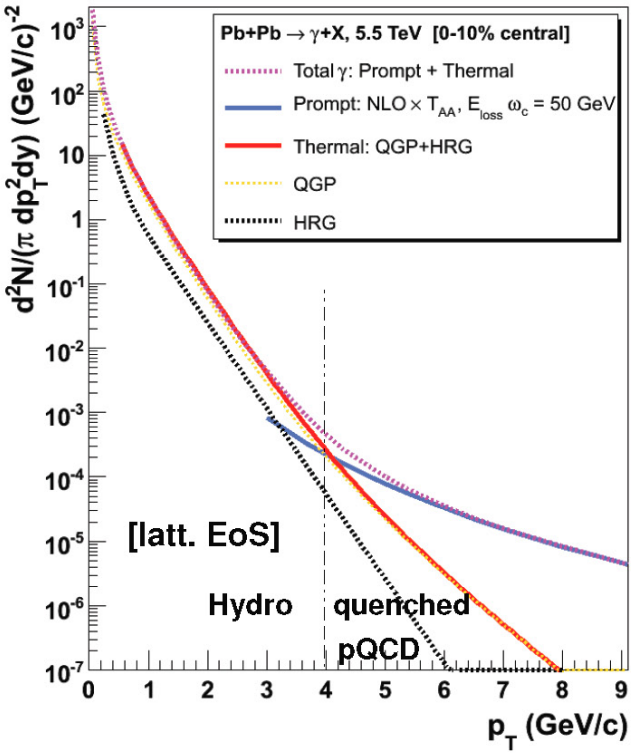
So far, only pQCD spectral function has been used

Photon spectrum calculation

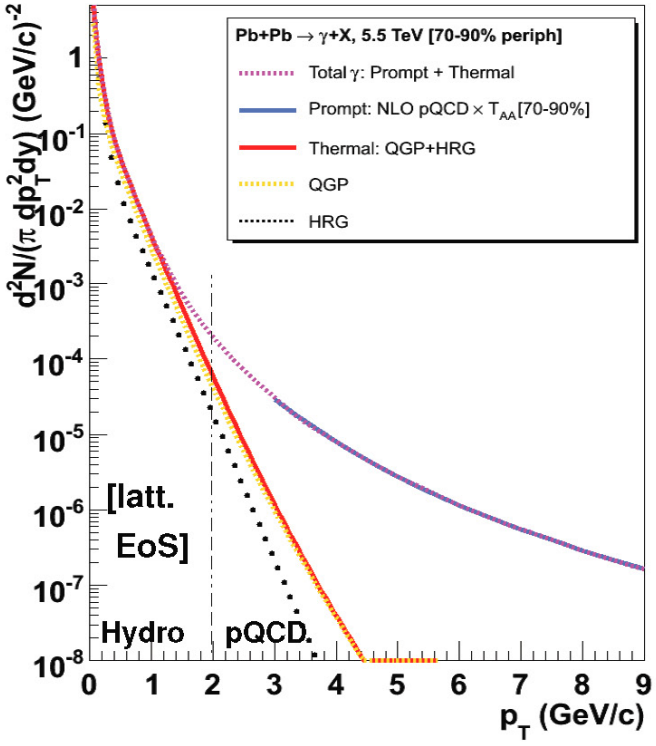
Direct γ spectra: hydro+pQCD prediction (LHC)

Photon spectra: hydro + (quenched) NLO pQCD:

Pb-Pb 0-10% central (<b> ~ 3 fm)



Pb-Pb 70-90% periph. (<b> ~ 14 fm)

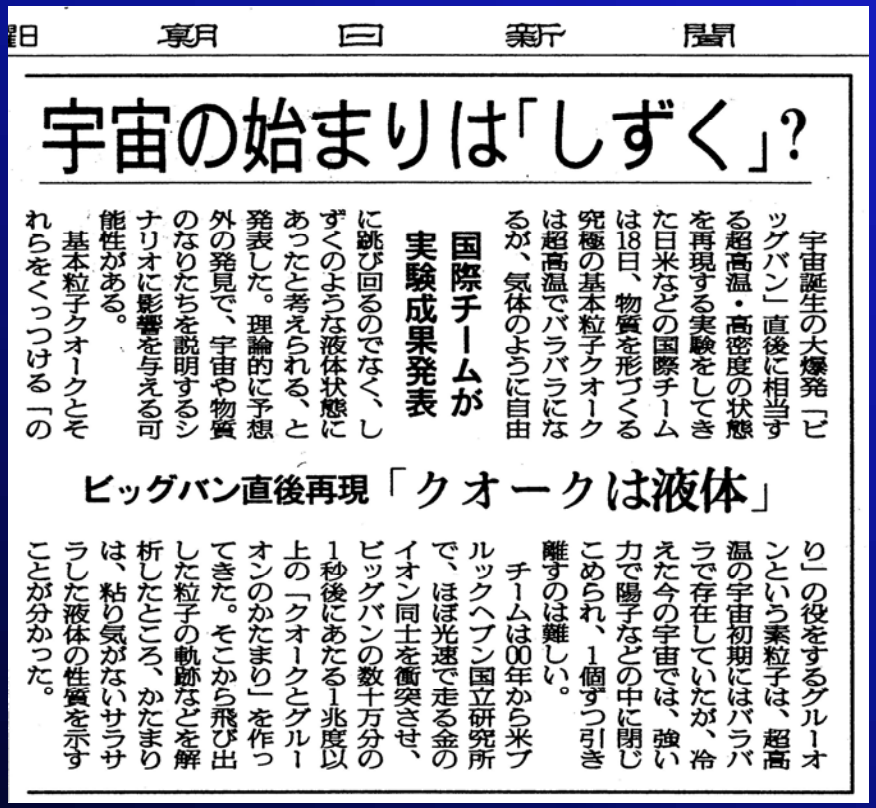


Last Call HI-LHC, May 29th, 2007 12/13 David d'Enterria (CERN)

D'Enterria, LHC workshop @CERN 2007

- Photonの陰： Hadron相のdileptonと比べて構造が平坦

One of the most striking findings @RHIC



朝日新聞

宇宙の始まりは「しずく」?

宇宙誕生の大爆発「ビッグバン」直後に相当する超高温・高密度の状態を再現する実験をしてきた日米などの国際チームは18日、物質を形づくる究極の基本粒子クォークは超高温でバラバラになるが、気体のように自由

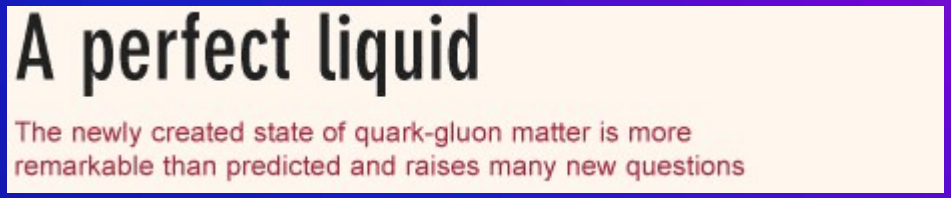
国際チームが実験成果発表

に跳び回るのでなく、しずくのような液体状態にあったと考えられる、と発表した。理論的に予想外の発見で、宇宙や物質のなりたちを説明するシナリオに影響を与える可能性がある。

基本粒子クォークとそれらをくっつける「のり」の役をするグルーオンという素粒子は、超高温の宇宙初期にはバラバラで存在していたが、冷えた今の宇宙では、強い力で陽子などの中に閉じこめられ、1個ずつ引き離すのは難しい。

チームは00年から米ブルックヘブン国立研究所で、ほぼ光速で走る金のイオン同士を衝突させ、ビッグバンの数十万分の1秒後にあたる1兆度以上の「クォークとグルーオンのかたまり」を作ってきた。そこから飛び出した粒子の軌跡などを解析したところ、かたまりは、粘り気がないサラサラした液体の性質を示すことが分かった。

ビッグバン直後再現「クォークは液体」



A perfect liquid

The newly created state of quark-gluon matter is more remarkable than predicted and raises many new questions

"The beginning of the universe is a drop?"

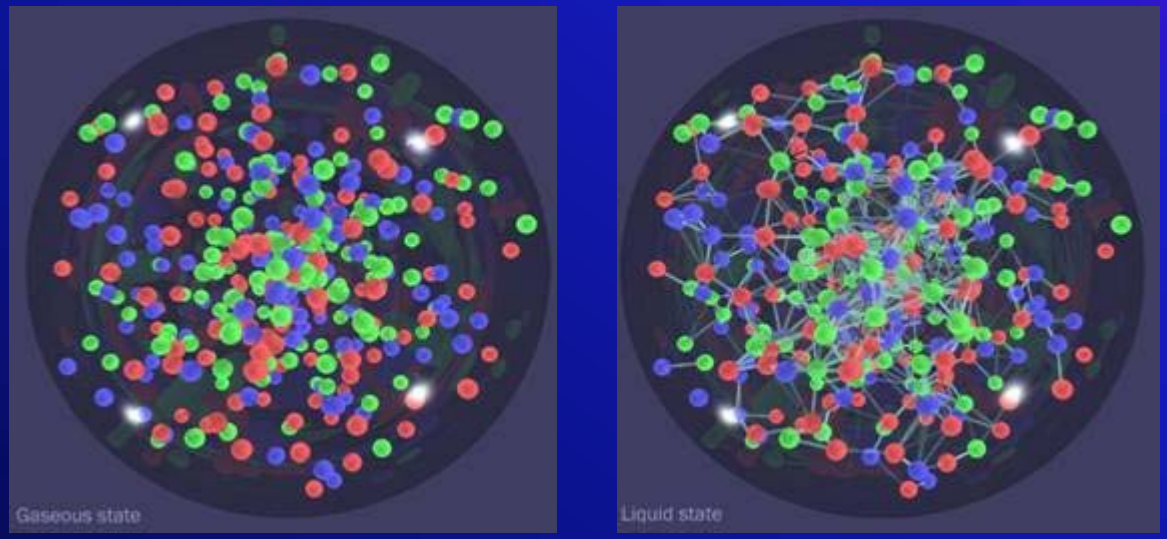
"The quark is liquid"

Asahi Shinbun, April 2005

Possible Formation of
Strongly Interacting Matter

Strong coupling: not necessarily perfect liq.

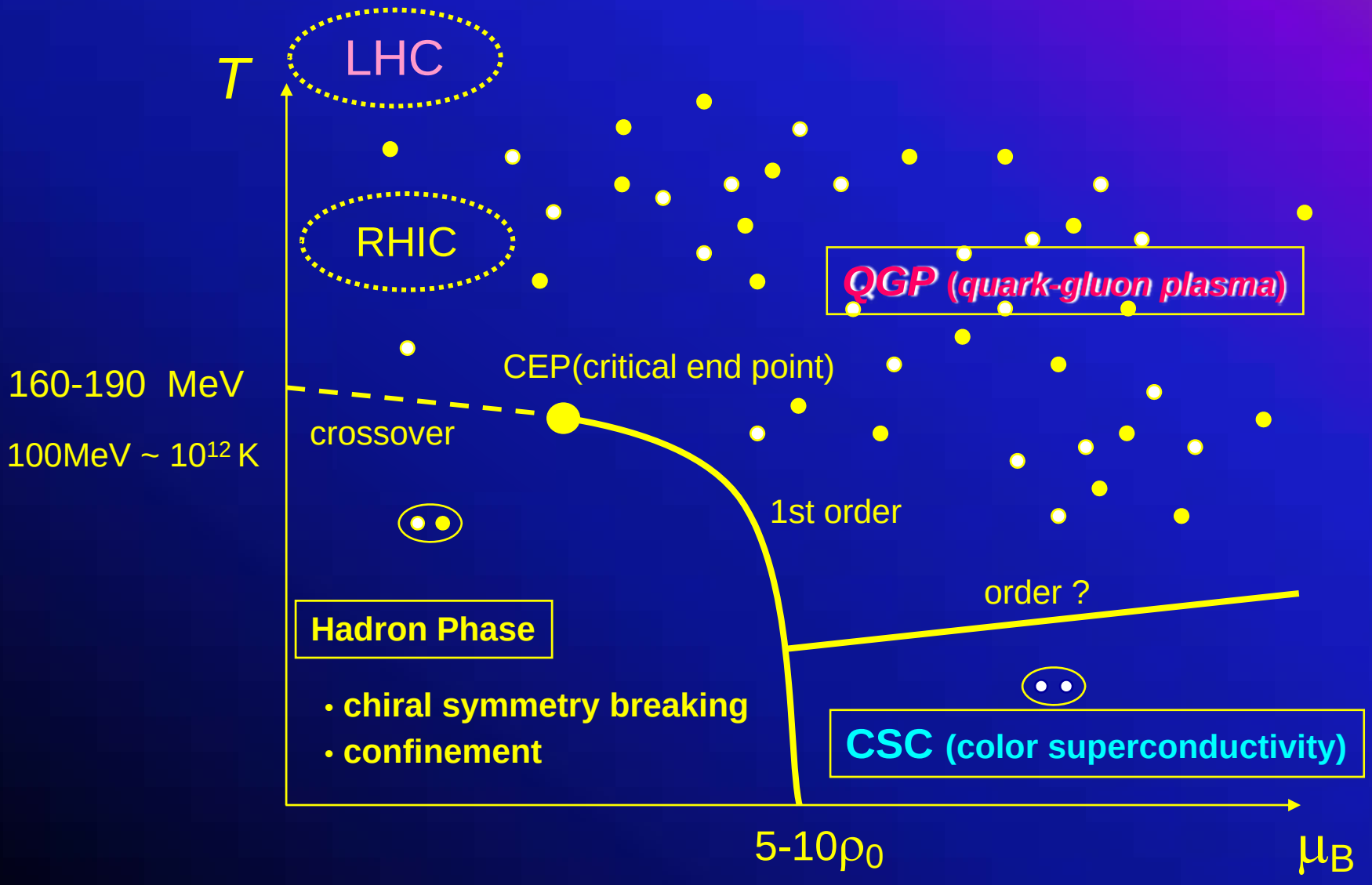
- Low viscosity = Little momentum transport



Long range and many body correlation: leads to ***large*** viscosity

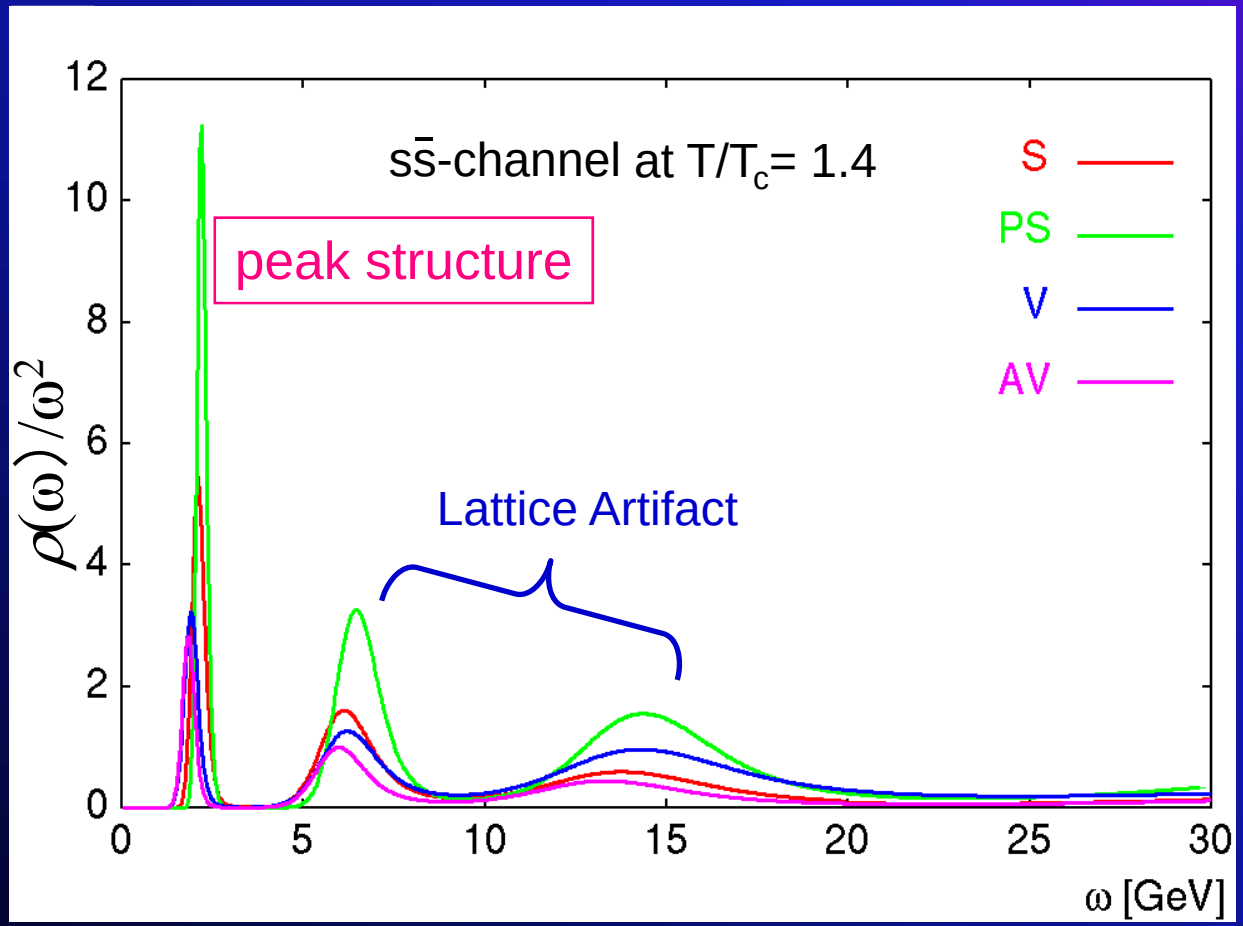
What is generally experienced in condensed matter physics

QCD Phase Diagram



Spectral Functions above T_c

$m_{ud} << m_s \sim T_c << m_c < m_b$



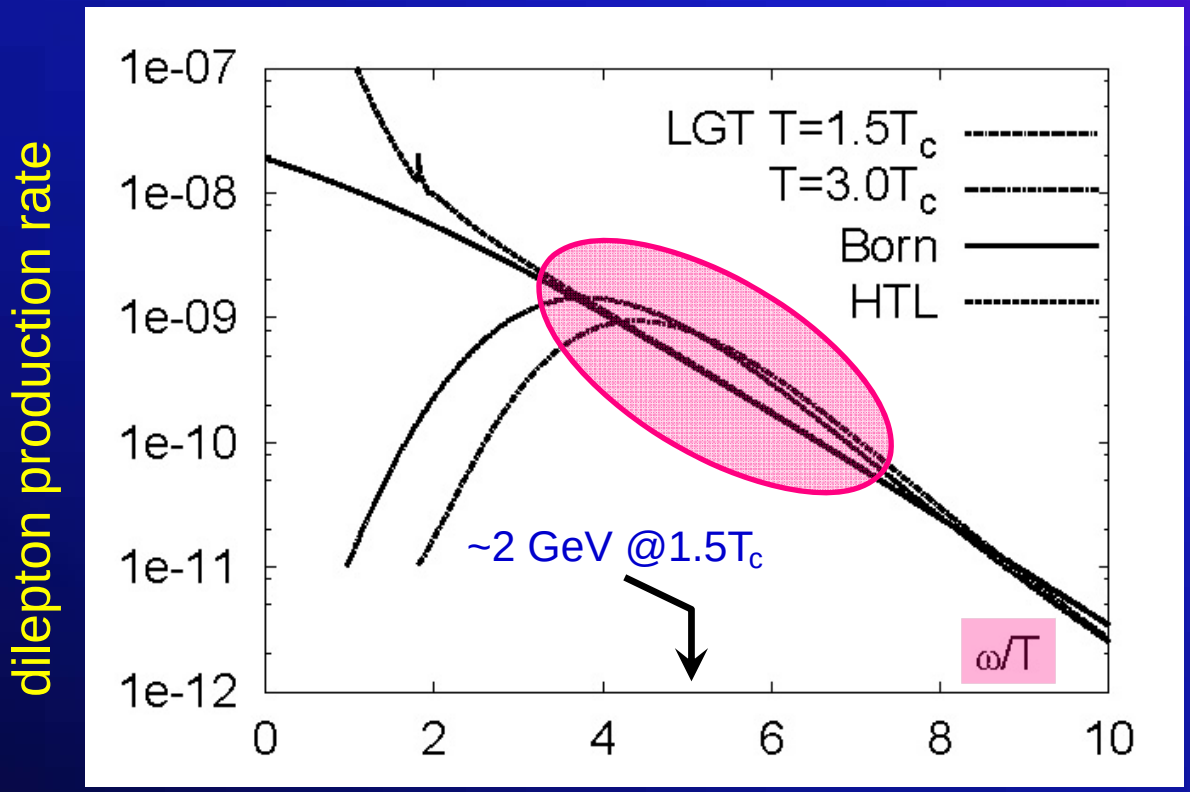
Asakawa, Nakahara & Hatsuda [hep-lat/0208059]

Another calculation

log scale!

massless quarks

smaller lattice



Karsch et al., 2003

How about for heavy quarks?