BNL workshop on
E/M probes. Dec.2012

Stony Brook University

New ideas on the Penetrating Probes

Edward Shuryak
Stony Brook University

outline

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- **"hot glue scenario"** **(ES,1992) + comment on anisotropy vs dilepton polarization (ES .2012)**

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- **(DIS on GLASMA) or (hydro stress tensor coupled to 2 photons) B A <=> 2^{+}, 0^{+} glue $O(T_{\mu\nu}AA)$** (Basar,Kharzeev,ES in

time=0

glasma time

outline, page 2

QGP

near Tc

- photon radiation rates <= quarks and gluons are not the only quasiparticles, **monopoles appear in large number and help to explain large scattering rates** (small viscosity). We need to include those collisions in photon rates

hadronic time

- news on chiral symmetry restoration

Two-Stage Equilibration in High Energy Heavy Ion Collisions

E. Shuryak
Department of Physics, State University of New York at Stony Brook, Stony Brook, New York 11794
(Received 9 March 1992)

Using the (lowest-order) perturbative QCD, we argue that high energy heavy ion collisions proceed via two stages: *equilibration of gluons* takes time $\tau_g \sim \frac{1}{2}$ fm/c, while *production and equilibration of quarks* needs time at least $\tau_q \sim 2$ fm/c. If so, the initial gluon plasma is much hotter than usually estimated, $T_g \sim 400$ MeV, which leads to enhanced charm production and significant modifications of other proposed signals.

fined by $d\sigma/dt = (\pi\alpha_s^2/s^2)M^2]$ are

$$M^2_{gg\to gg} = \frac{9}{2}\left(3 - \frac{ut}{s^2} - \frac{us}{t^2} - \frac{st}{u^2}\right),$$

$$M^2_{gg\to \bar{q}q} = \frac{1}{6}\frac{(u^2+t^2)}{ut} - \frac{3}{8}\frac{u^2+t^2}{s^2},$$

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Spectra of the produced *photons and dileptons* should also be significantly modified in this scenario: During the "transitory period" ($\tau_g < \tau < \tau_q$) one has *smaller* number of quarks, but those are *hotter*. The reason is again that $gg \to \bar{q}q$ is dominated by *small angles*, so the produced quarks have the same momentum distribution as gluons. As most photons and dileptons to be observed actually correspond to the *tails of the distribution functions*, it is important that their relaxation happens *from above*.

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charm contribution needs to be subtracted to test early dileptons M=1..3 GeV

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M.Heller et al
arXiv:1103.3452

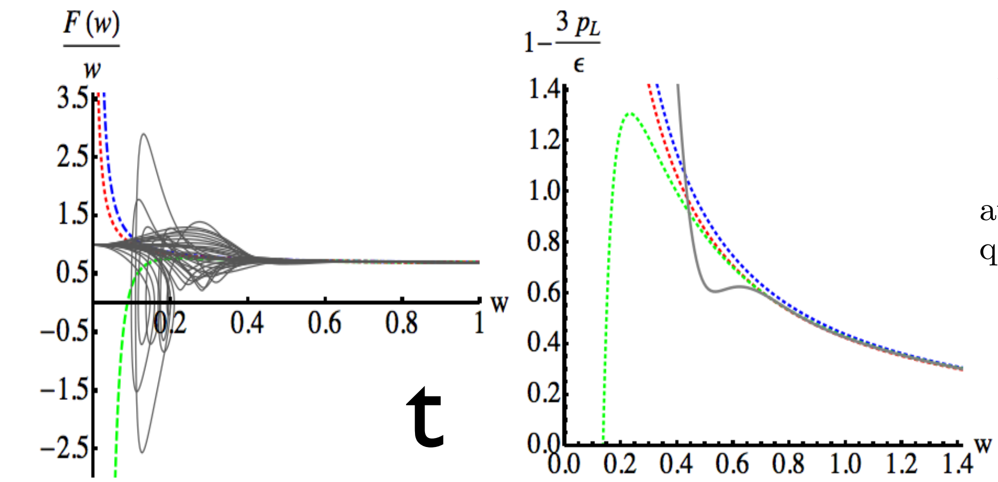

FIG. 1. a) $F(w)/w$ versus w for all 29 initial data. b) Pressure anisotropy $1 - \frac{3p_L}{\varepsilon}$ for a selected profile. Red, blue and green curves represent 1^{st}, 2^{nd} and 3^{rd} order hydrodynamics fit.

w=t T_0=t/(.5 fm) at LHC

AdS/CFT collisions with various initial conditions converge to the same hydro, and they do so **when anisotropy is still large!**

Monitoring parton equilibration in heavy ion collisions via dilepton polarization

Edward Shuryak

Department of Physics and Astronomy, State University of New York, Stony Brook, NY 11794

(Dated: March 6, 2012)

In this note we discuss how angular distribution of the dileptons produced in heavy ion collisions at RHIC/LHC energies can provide an information about a degree of local equilibration of the quark-gluon plasma produced at different invariant mass regions.

$$\frac{d\sigma}{d\Omega} \sim (1 + acos^2\theta)$$

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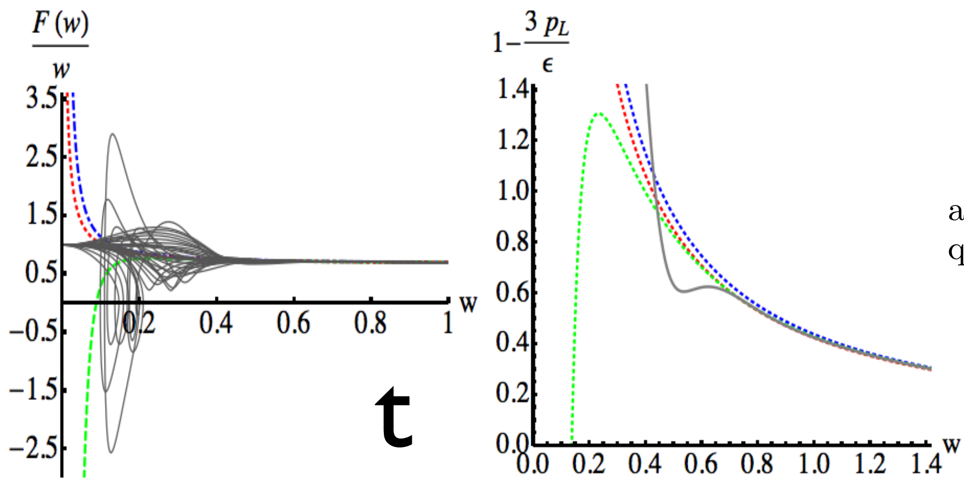

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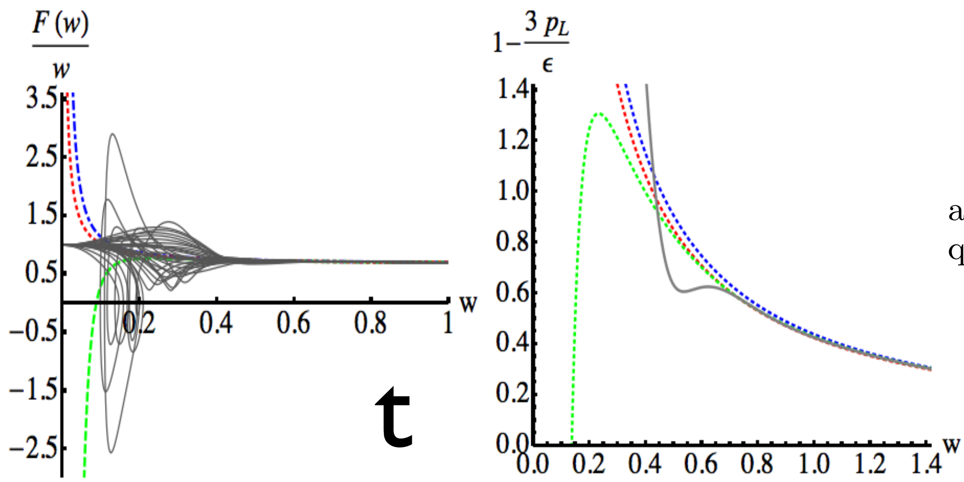

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dilepton polarization
a=1 for DY (partons come from the beam direction)
a=-0.2 if elongated in transverse plane
a=0 in thermal case

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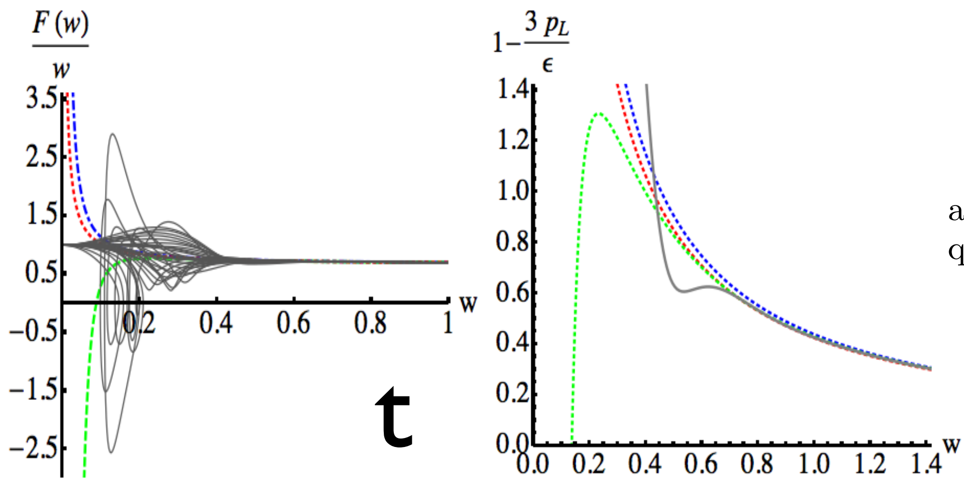

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Perhaps STAR/new PHENIX can catch out-of-equilibrium stage via a<0

Production of soft e^+e^- Pairs in Heavy Ion Collisions at RHIC by Semi-coherent Two Photon Processes

coherent Z^2

incoherent P's Z

``exotic''

Pilar Staig and Edward Shuryak
Department of Physics and Astronomy
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(Dated: May 20, 2010)

We calculate the contribution of the two photon production process into e^+e^- spectra, and c
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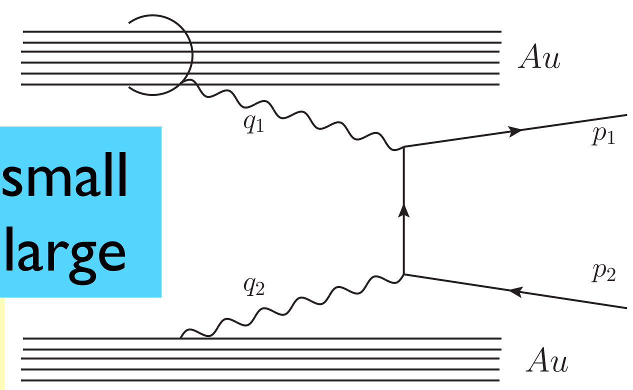
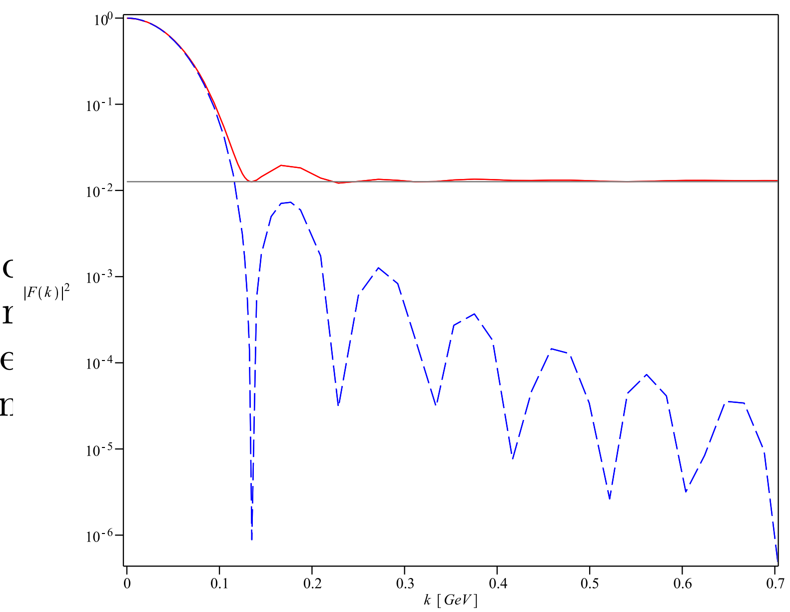
q1 small
q2 large



- ultra-peripheral is coherent-coherent
- parton processes are incoherent-incoherent
  gq=>gamma q
- semi-coherent has coherent field with small q1 and incoherent one with large q2 (resolving protons)



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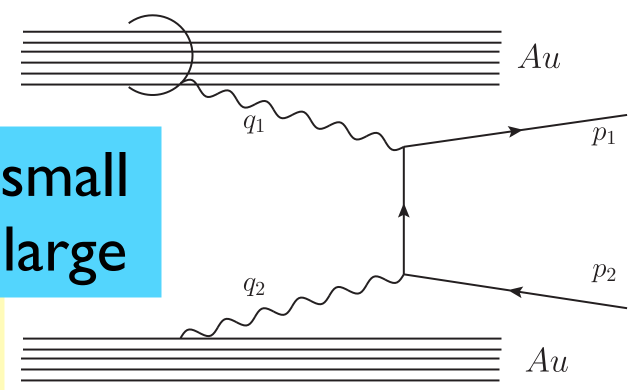

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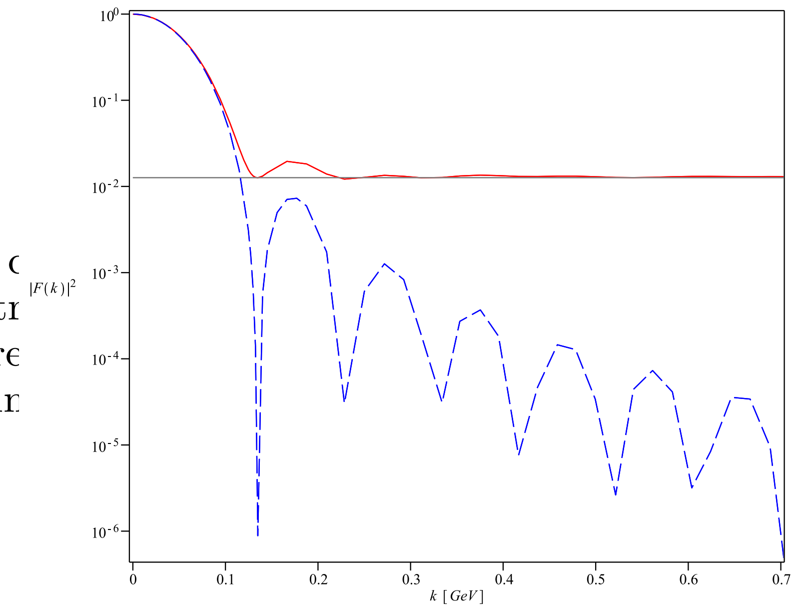

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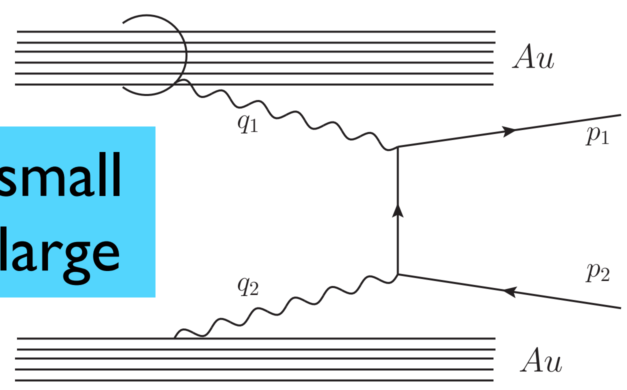

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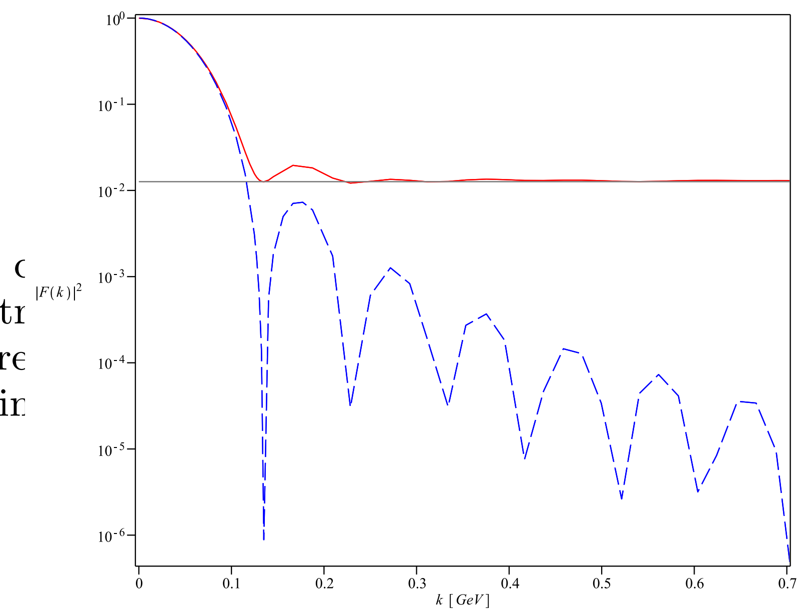

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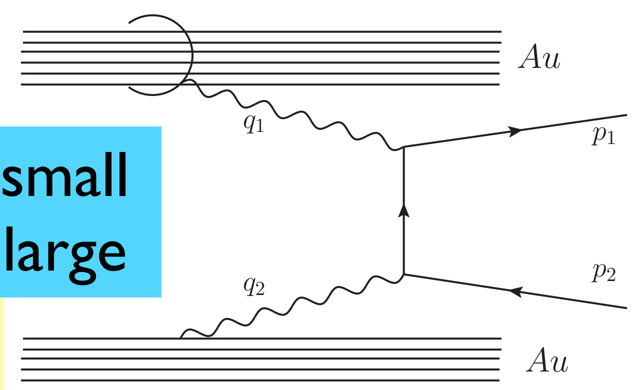

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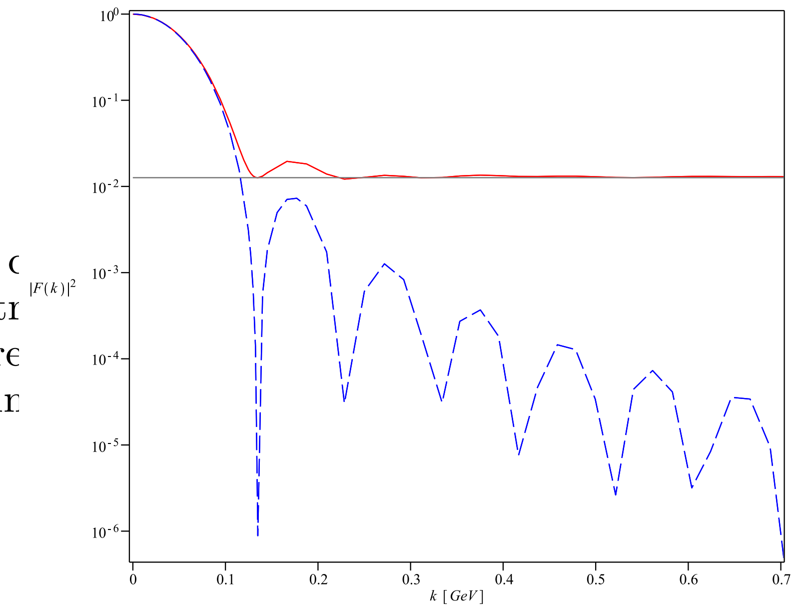

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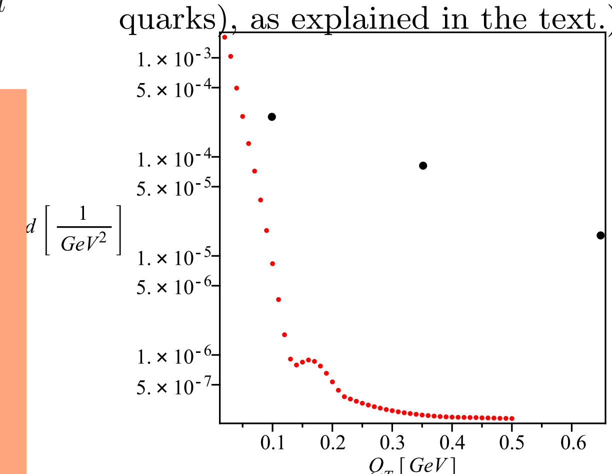

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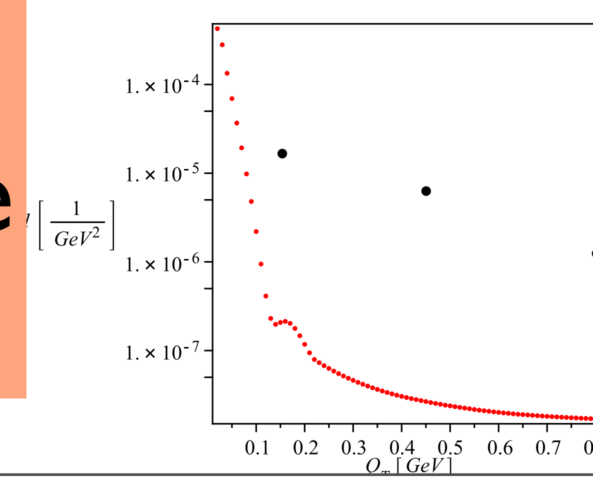

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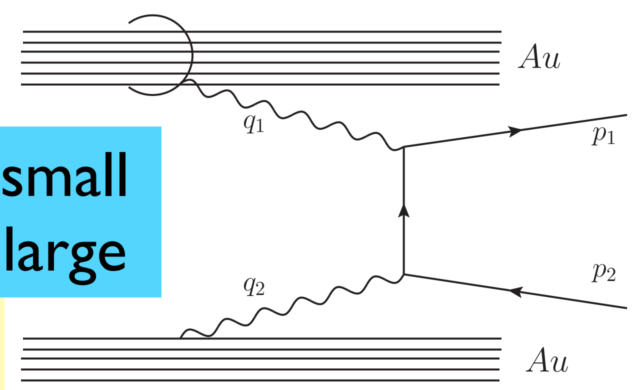

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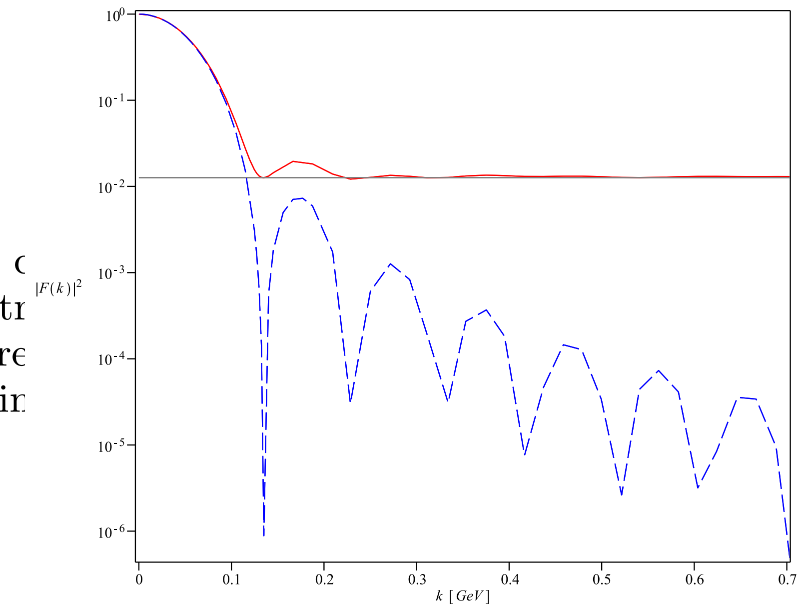

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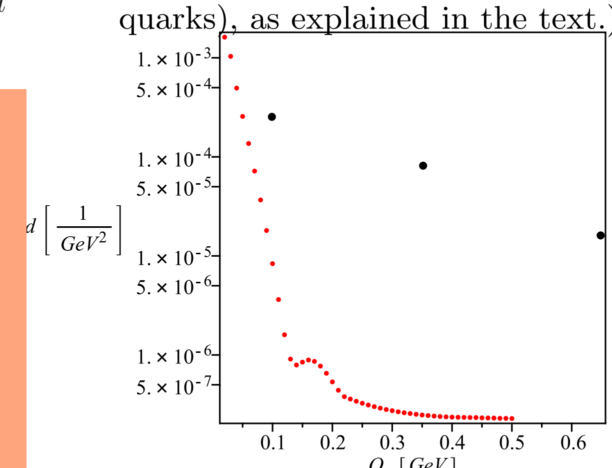

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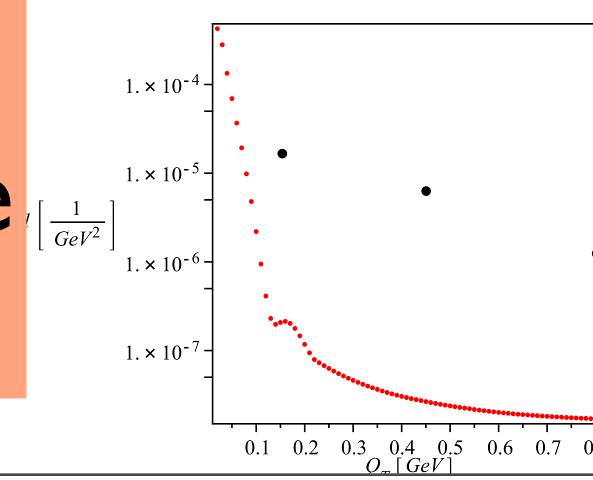
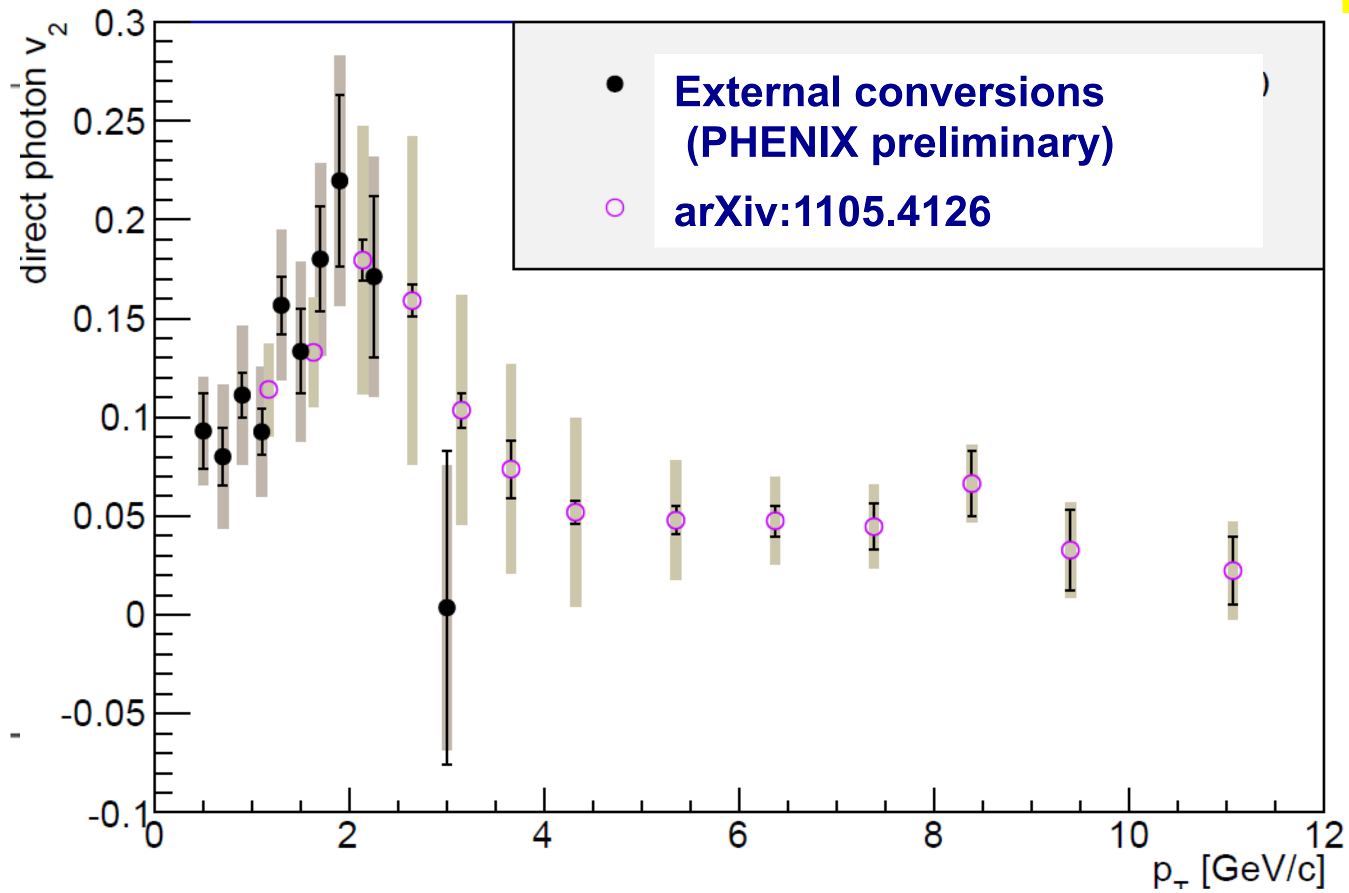


M=.81..0.99 GeV

New puzzle: large v2 of photons (Phenix)

=> v2 is as large as that for hadrons
=> seems to persist even at large pt (?)
=> also seen by ALICE

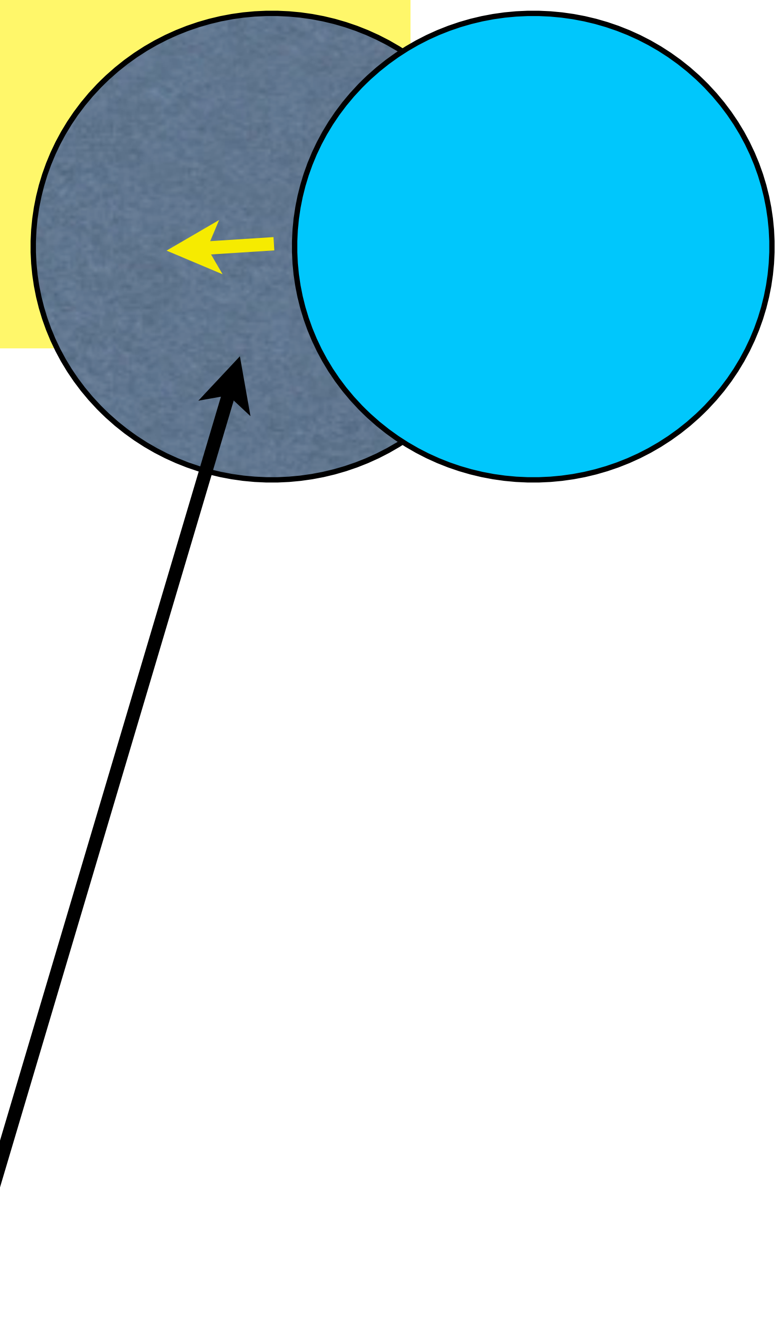


- q+**(semi-coherent eff.photon)**=>q+gamma

(with J-F. Liao) (WW approximation)

- q+ (B-correlated gluon) =>q+gamma

$$Z\alpha \sim \alpha_s$$



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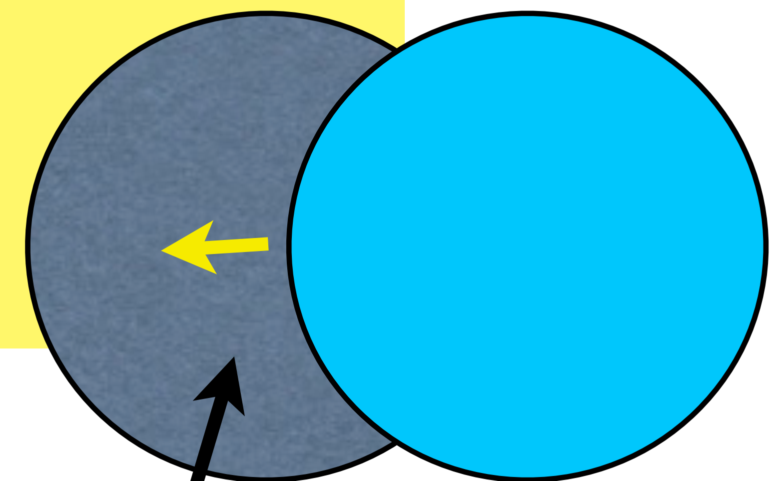


while $Z\alpha \sim \alpha_s$
effective gluon density is O(10) larger than equivalent photons,

but photon's momentum is **strongly correlated with the impact parameter b**

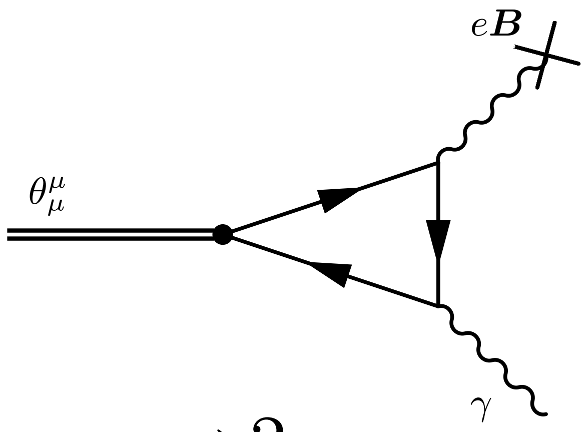
coherent E/B field of the photon extends beyond the edge of the nuclei

even small effects need to be calculated!

Basar,Kharzeev,Skokov arXiv:1206.1334

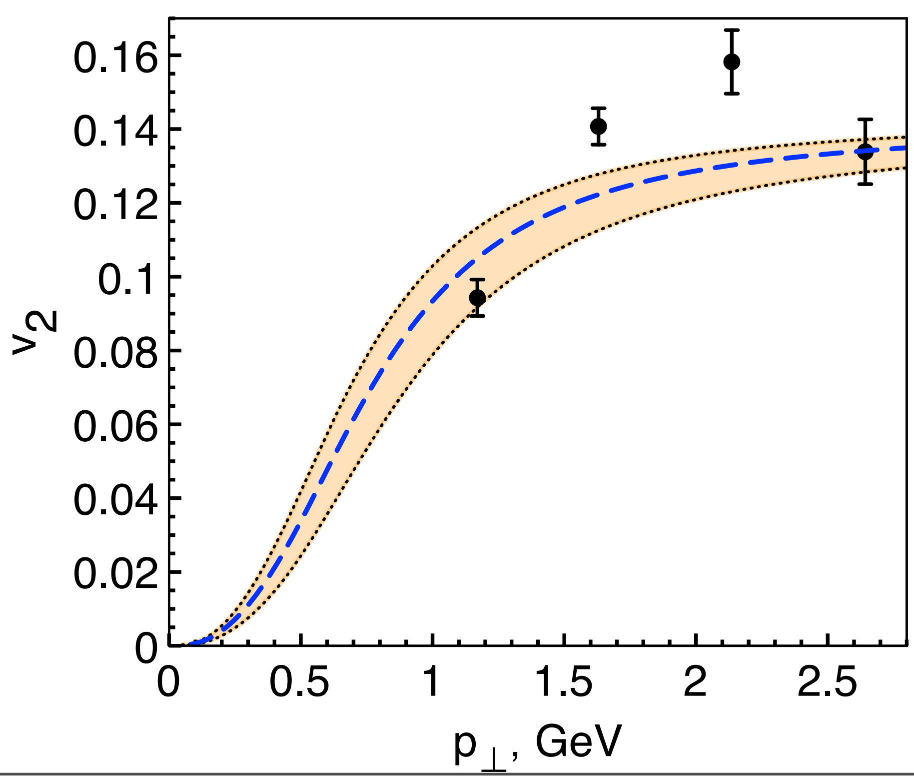
(1)virtual quark loop
(2)coherent magnetic field
(3)B+photon mix with scalar G^2
(4)Its correlators are related to bulk viscosity and correlators

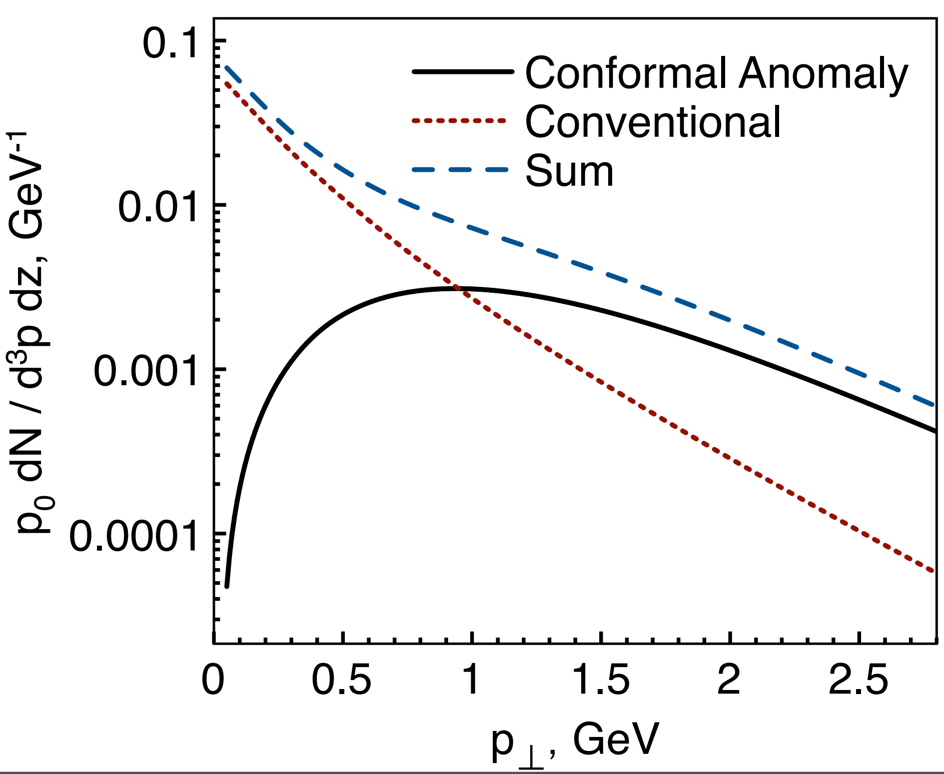
Spectral densities known from AdS/QCD models



$$\sim (B_y q_x^\gamma)^2$$

no effect along the B field!





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The tensor channel

Basar, Kharzeev, ES, in progress

$\vec{E}^2 - \vec{B}^2$ $\vec{E}^2 + \vec{B}^2$

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- Why G^2 and not $T_{\mu\nu}$? **Fermionic loop couples to both, and 2+ has more components**

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- **Formfactors? B has energy q^0 of couple GeV, another photon can be virtual (=> dileptons)**

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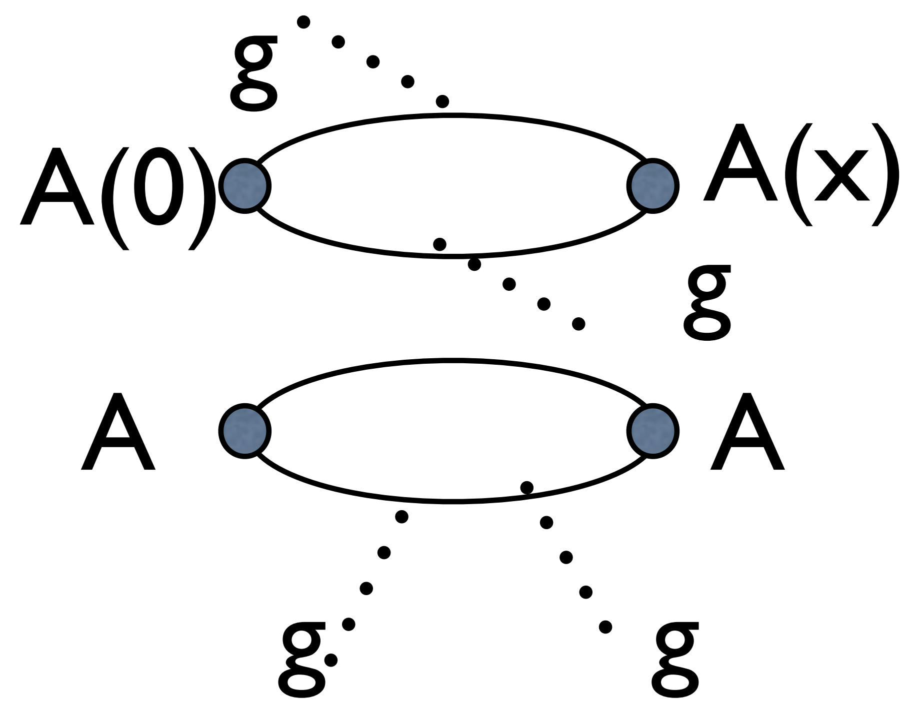
- 2 OPE cases: (i) γγ hard, gg soft; (ii) γγ soft, gg hard. Calculation follows ES, Vainshtein **Nucl.Phys. B201 (1982) 141** and the result is not naive products of two stress tensors

$$L_{eff} = \Pi_{\mu\nu} A_\mu A_\nu$$

$$\Pi_{\mu\nu} = Tr(\gamma_\mu S(q,G)\gamma_\nu S^+(q,G))$$



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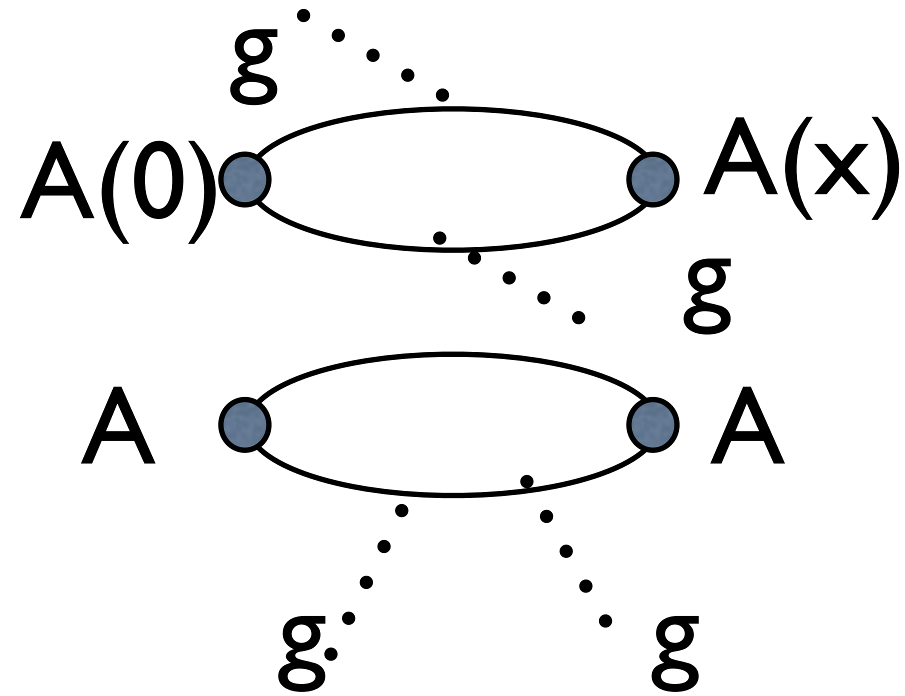

the usage of the so called fixed-point gauge

$$x_\mu A_\mu(x) = 0 \qquad (12)$$

invented by Fock, Schwinger and perhaps others. In this gauge $A_\mu(0) = 0$ and next order terms in x expansion can be written as covariant derivatives of the field strength

$$A_\mu(x) = \sum_{k=0} \frac{1}{k!(k+2)} x_\nu x_{\alpha_1} \ldots x_{\alpha_k} (D_{\alpha_1} \ldots D_{\alpha_k} G_{\mu\nu}(0))$$

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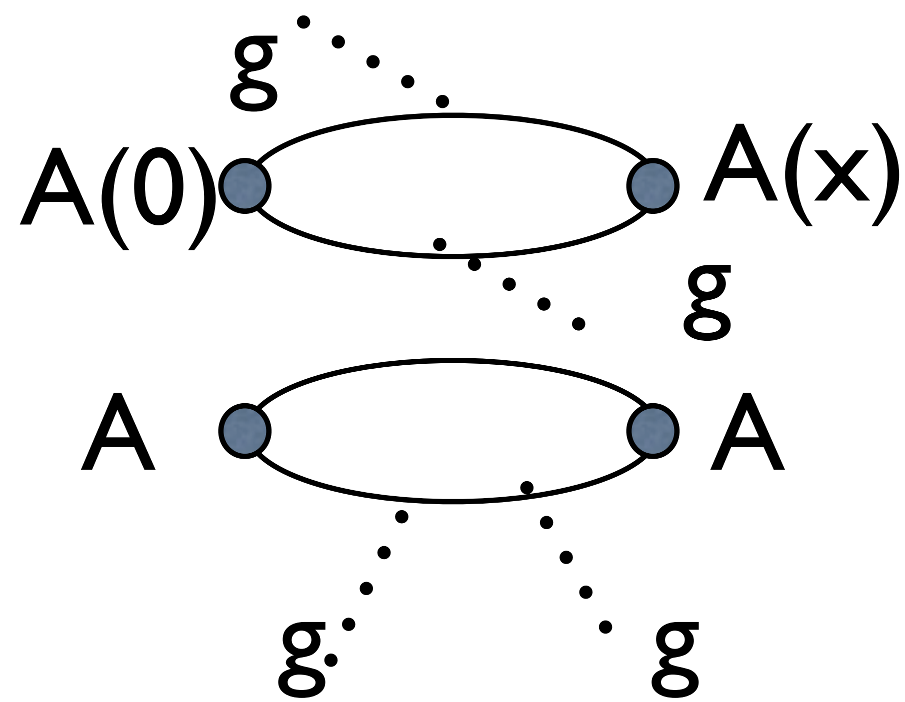

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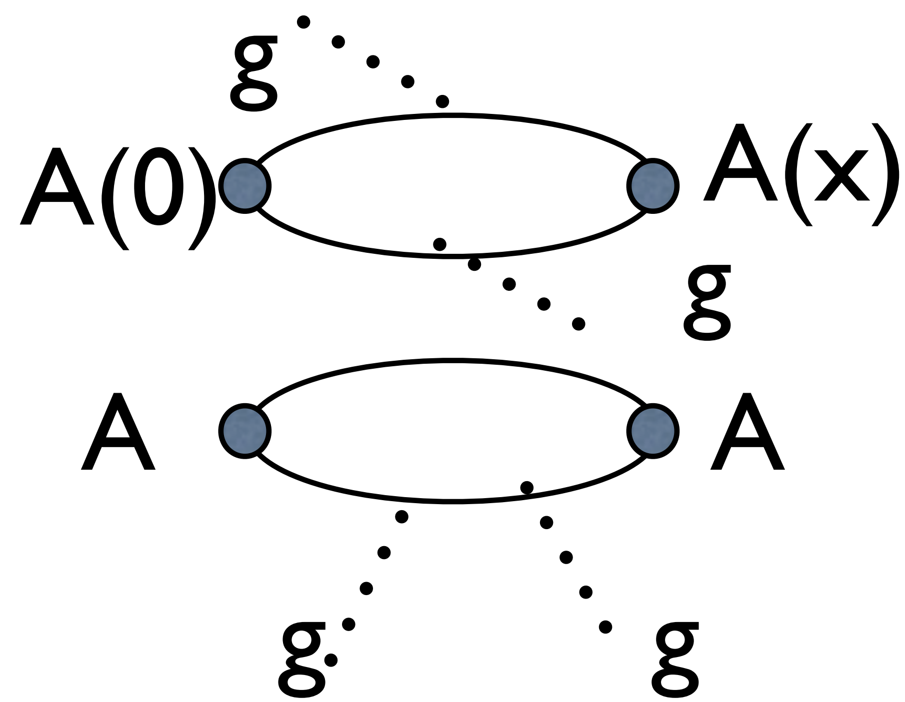

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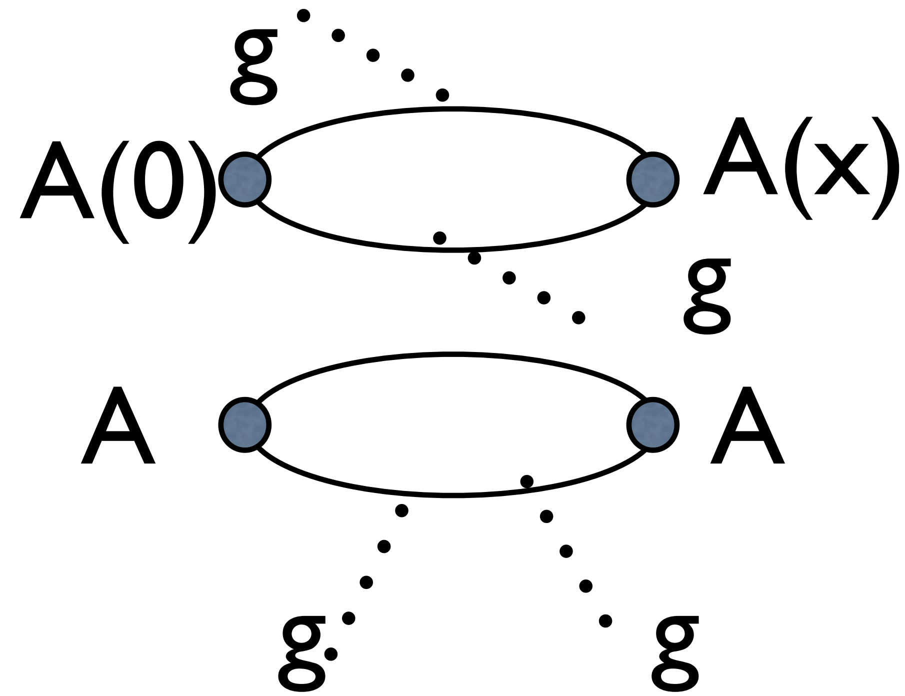

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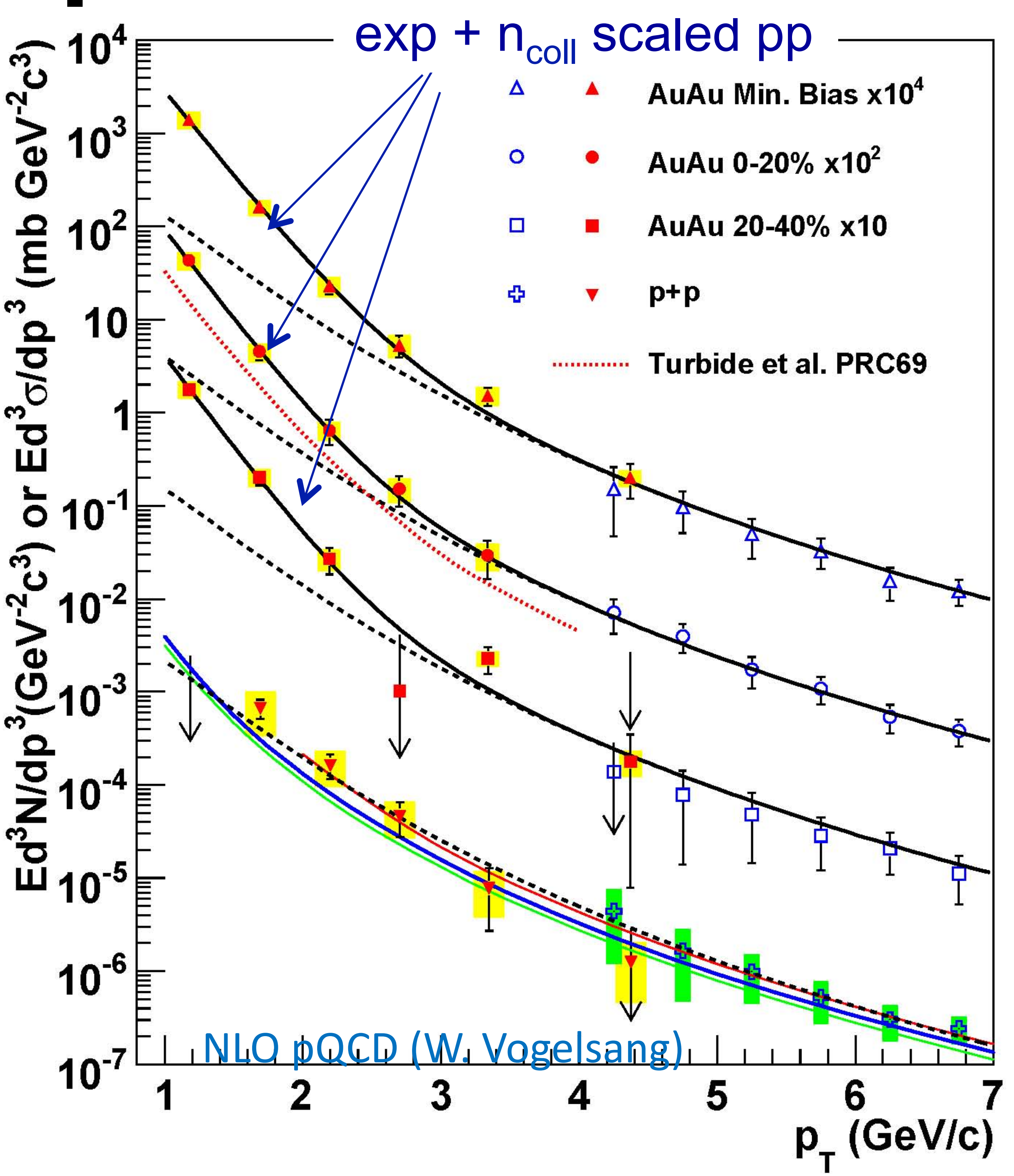
we have local effective interaction GG AA/q4 which of course preserve both gauge invariances

PHENIX photons

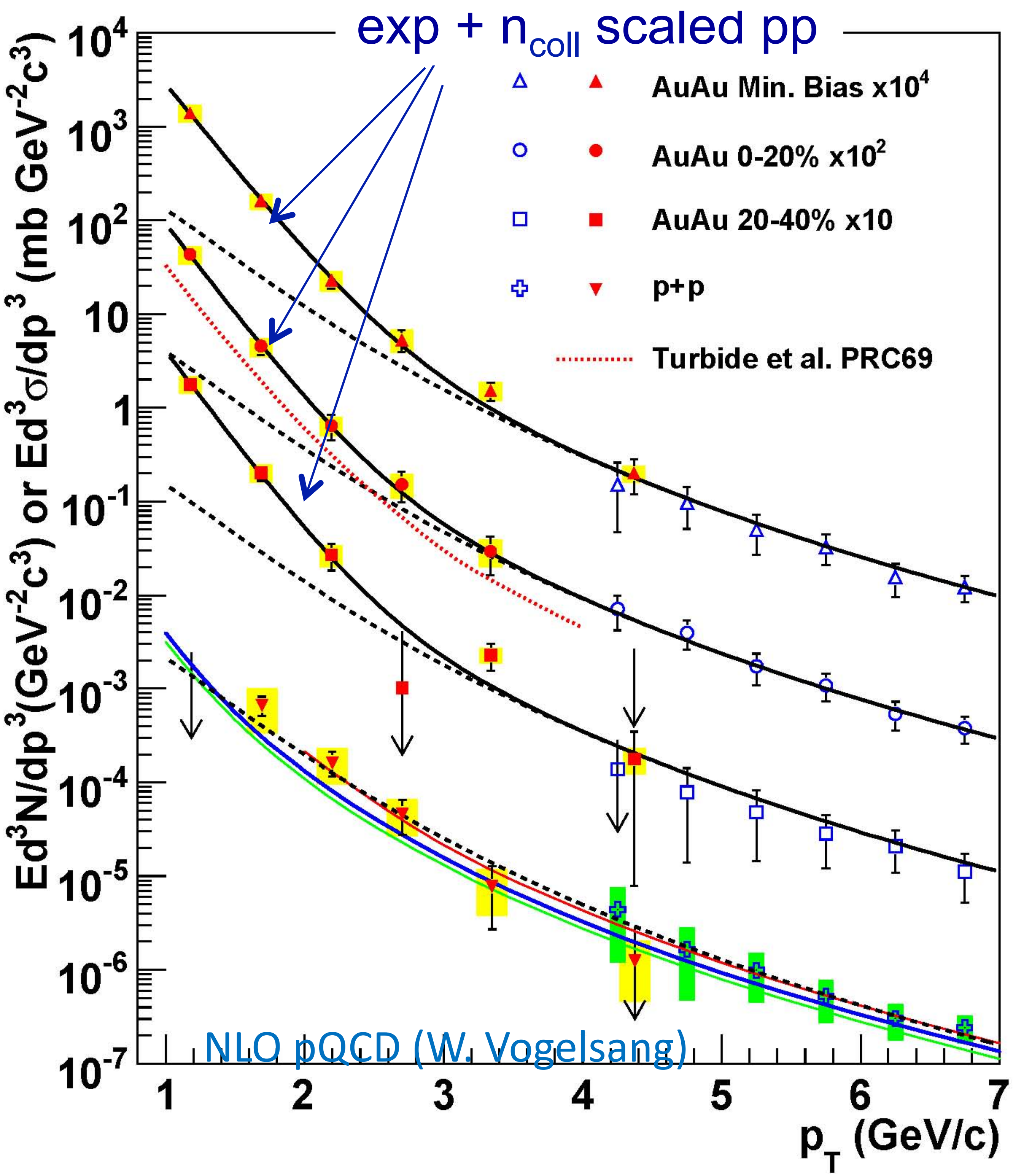
pQCD describes the pp case



PHENIX photons

pQCD describes the pp case

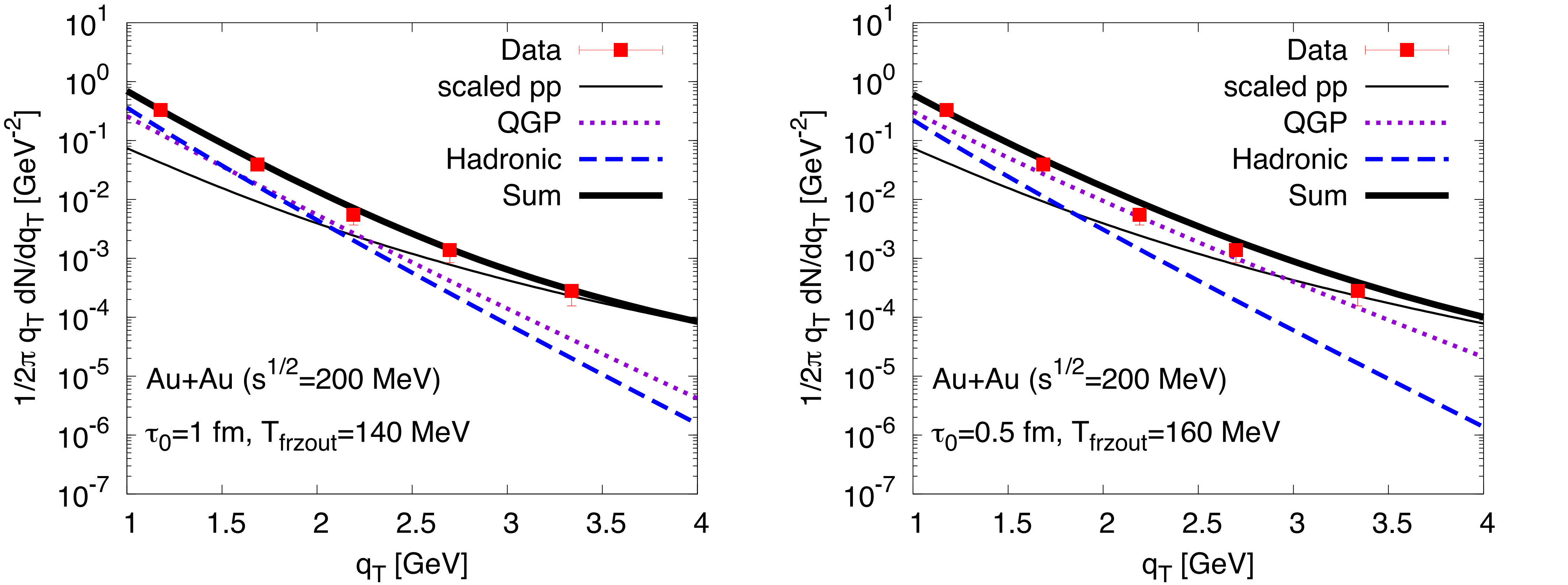
Note that Turbide et al miss a factor 2..3 in the rate.
Hadronic rate is calculated from a gas of pions,K,rho,K*, A1 plus baryons (rho-N resonances)
QGP rate is the HTL-corrected QCD Compton



Kevin Dusling[a] and Ismail Zahed[b]

ArXiv: 0911.2426

Are the rates too small?



'IG. 9: Photon spectra at RHIC compared to the recent PHENIX data. The left plot is the volution set RHIC 1 and the right is for RI

seems OK in this work, but this is for alpha_s=0.75!

photons from QGP

(my original QGP paper, 1978) +HTL completion to it (Kapusta et al, PRD44, 1991)

$gq \to q\gamma, qq \to g\gamma$

$$q_0 \frac{dR_\gamma}{d^3q} = \frac{6}{9} \frac{\alpha\alpha_S}{2\pi^2} T^2 e^{-q_0/T} \ln\left(1 + \frac{2.912}{4\pi\alpha_s} \frac{q_0}{T}\right) ,$$

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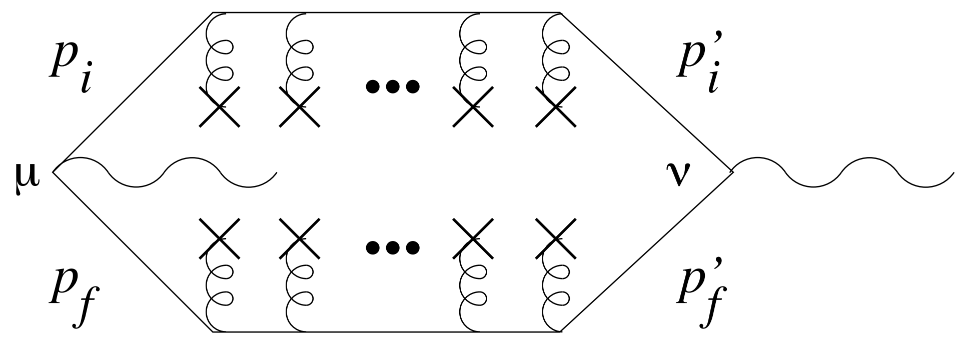

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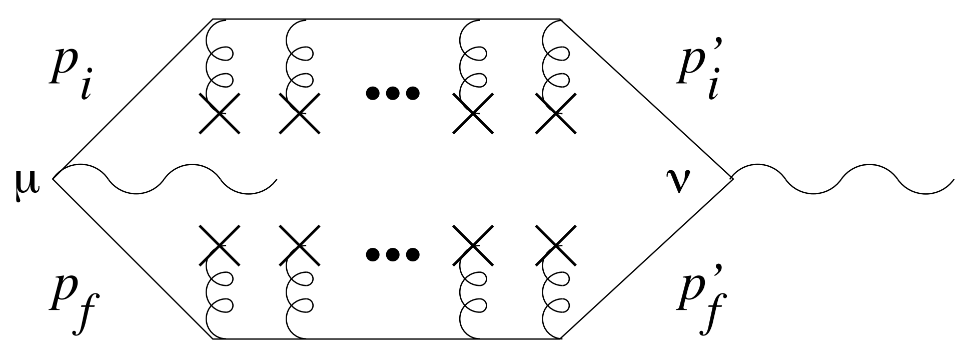

may work at large pt,
otherwise pQCD series does not converge
perhaps, strong coupling methods needed

should there be extra contribution to the perturbative photon radiation rates?

(one expects it for e.g. **viscosities)**

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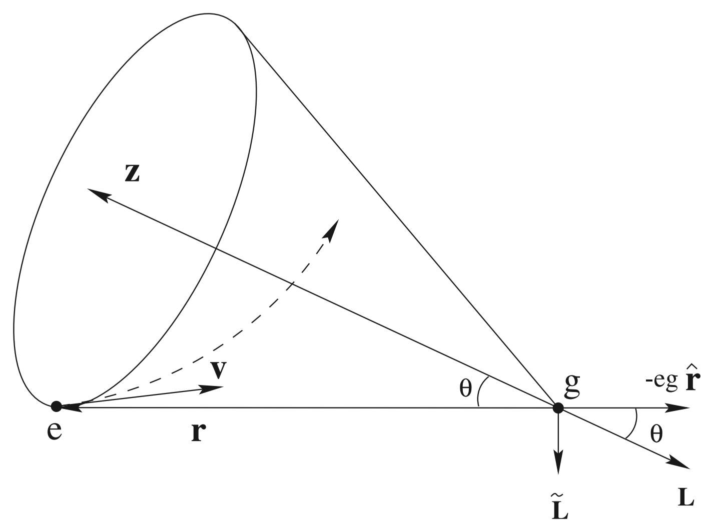
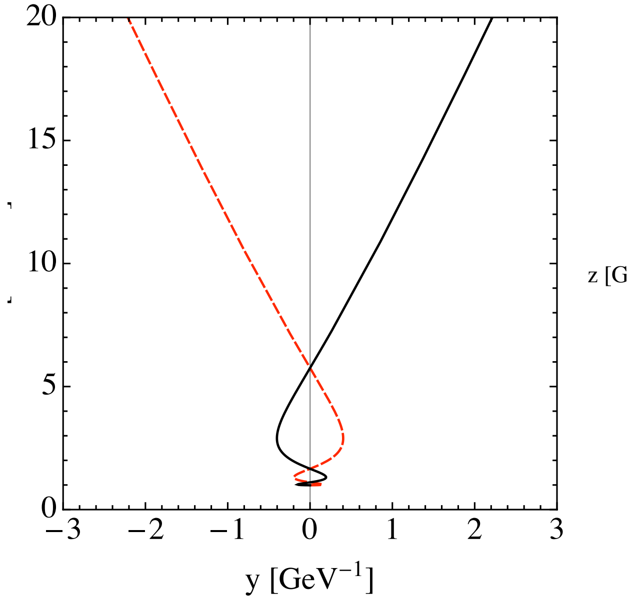
- Same with electomagnetic rates

monopoles contribute to viscosities, via large angle scattering

$$\vec{B} = g\frac{\vec{r}}{r^3}.$$





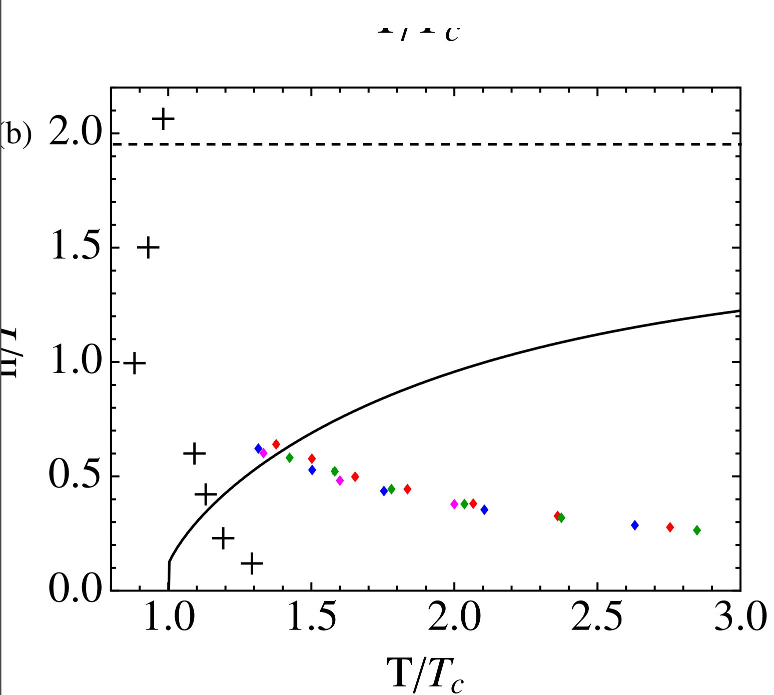
$$m\frac{d^2\vec{r}}{dt^2} = e\vec{v}\times\vec{B} = \frac{eg}{r^3}\frac{d\vec{r}}{dt}\times\vec{r};$$

PHYSICAL REVIEW D **80,** 034004 (2009)

Role of monopoles in a gluon plasma

The motion of an electric charge in the field of a magnetic monopole.

Claudia Ratti and Edward Shuryak*
onomy, State University of New York at Stony Brook, Sto
(Received 4 February 2009; published 5 August 2009)



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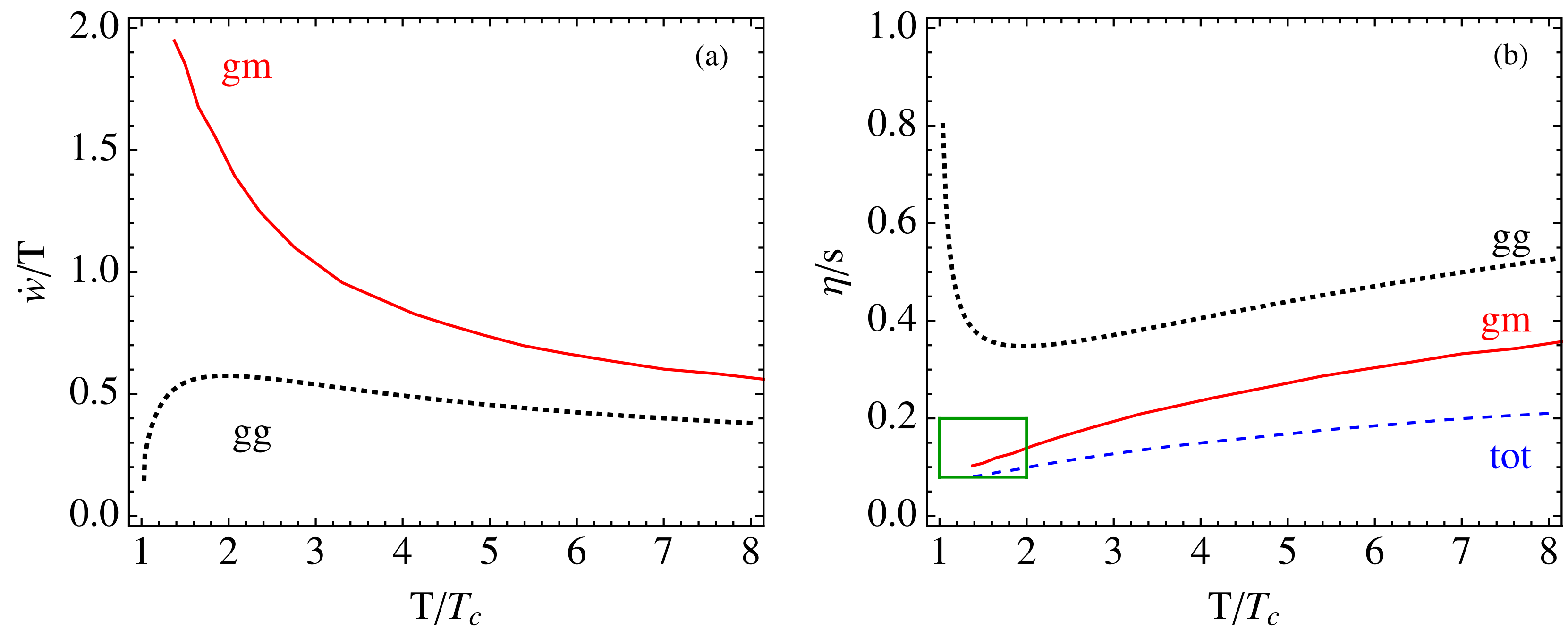
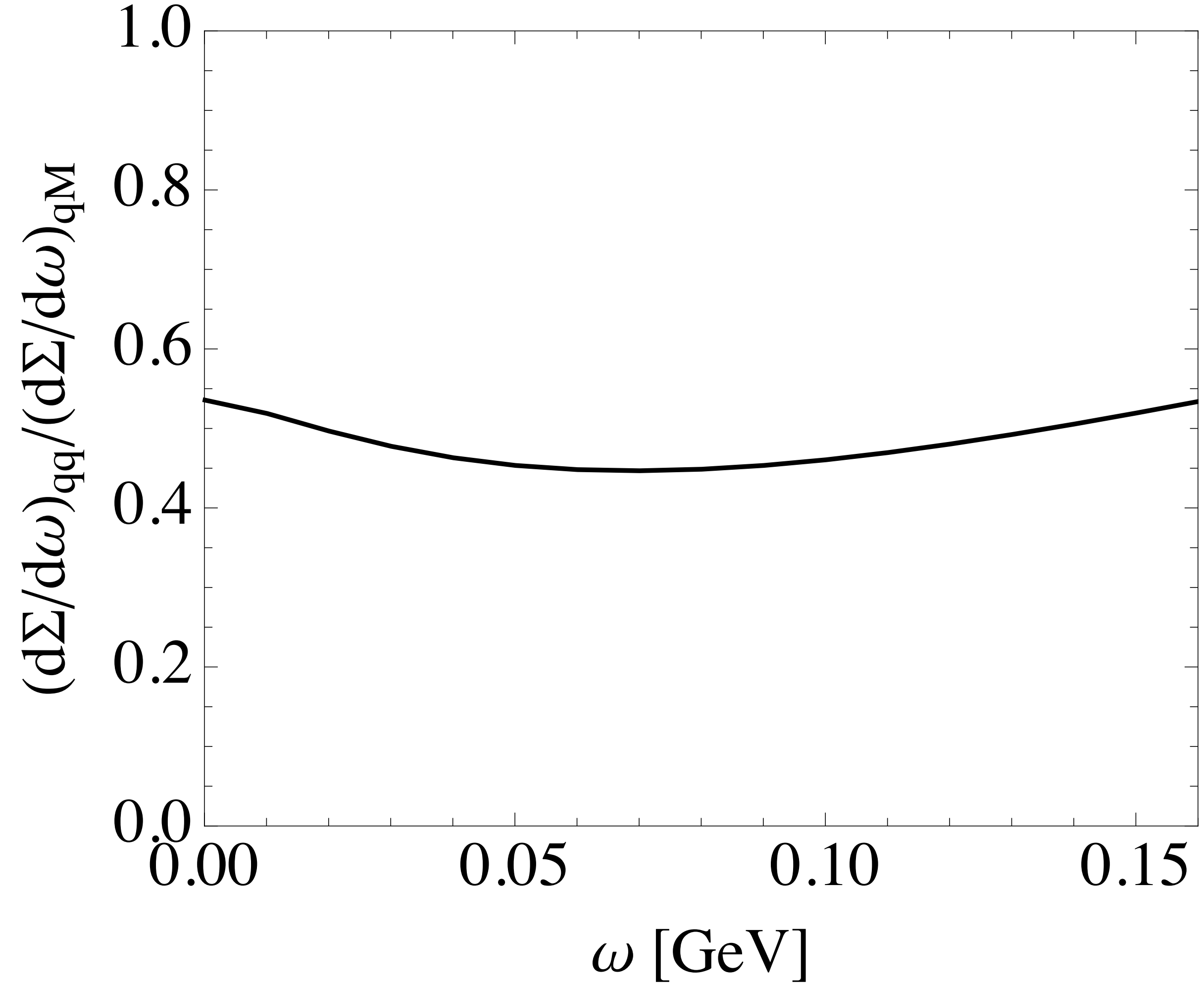


FIG. 15 (color online). (a) gluon-monopole and gluon-gluon scattering rates. (b) gluon-monopole and gluon-gluon viscosity over entropy ratio, η/s. The blue, dashed curve is the total η/s, which is evaluated from the gg and gm contributions. The green box represents the present estimate of η/s in the RHIC temperature regime.

monopoles contribute to the photon radiation:

Radiation of an electric charge in the field of a magnetic monopole

Michael Lublinsky[a,b], Claudia Ratti[a,c], Edward Shuryak[a]



disclaimer:
only soft photons calculated classically from the trajectories

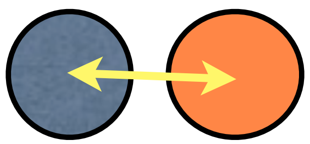
qM rate in RHIC condition is about twice that for qq (=> qq gamma)

comments about chiral symmetry restoration

- Kapusta+ES, 1993 Weiberg-type sum rules for <VV-AA> correlator (Rapp revived recently)
- yet it was unclear how pion,rho,A1,rho' move as T grows (hard on the lattice as Matsubara box shrinks), e.g. rho=>pi, rho'=>A1 (Brown-Rho); or **no pion, rho=>A1**; or nobody moves and **all melt (???)**
- lattice thermodynamics, especially mu-derivatives suggest BARYONS get heavier. The **mass LR term disappears** but energy (LL+RR) appear and compensates

chiral breaking is due to small subset of **states, ZMZ**

and its width is small (ES,1982)



given by the magnitude of the hopping from one instanton to the next

$$T_{I\bar{I}} \sim \frac{\rho^2}{R^3} \sim \frac{(0.3fm)^2}{(1fm)^3} \sim 20MeV$$

- people found it on the lattice and showed pions are completely described by ZMZ
- that is why quark mass dependence is nontrivial, and chiral perturbation

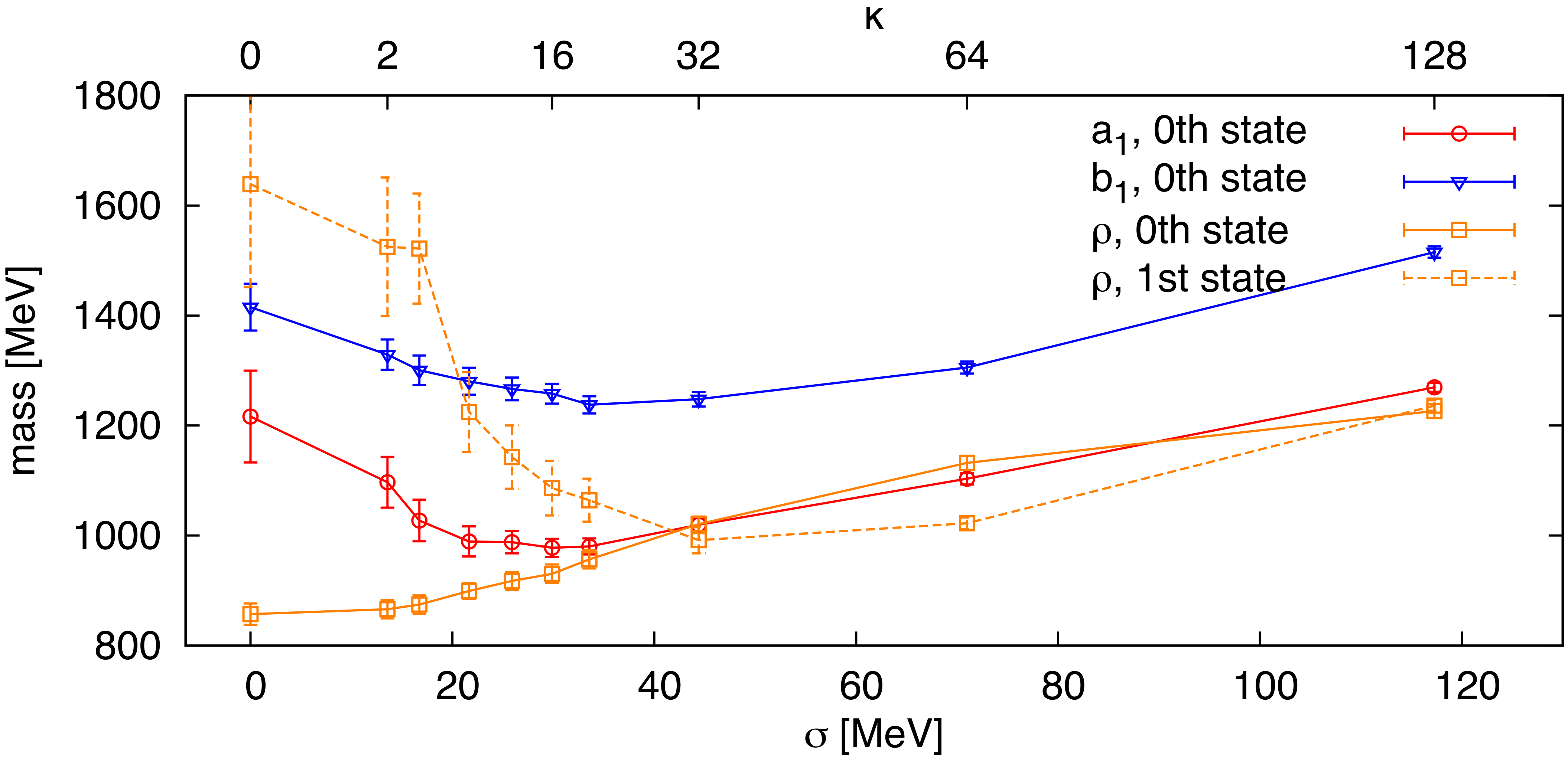
recently the opposite exercise was done by the Graz group

Symmetries of hadrons after unbreaking the chiral symmetry

L. Ya. Glozman,* C. B. Lang,† and M. Schröck‡
Institut für Physik, FB Theoretische Physik, Universität Graz, A–8010 Graz, Austria

By eliminating narrow band of modes 1/10000 one finds that **A1 moves down while rho only slightly go up**

near-perfect chiral pairs are left, nearly the same in average => thus resonance gas works



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- photons: small (nonpert) viscosity=> large (nonpert) gamma radiation rates.
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- example: interplay of strong **coherent QED fields** with partonic reactions, including **virtual quark loops**