Theory of heavy quark energy loss… , including lessons ***we*** have learned from RHIC (and early LHC data).

ISMD 2011 Miyajima-Hiroshima

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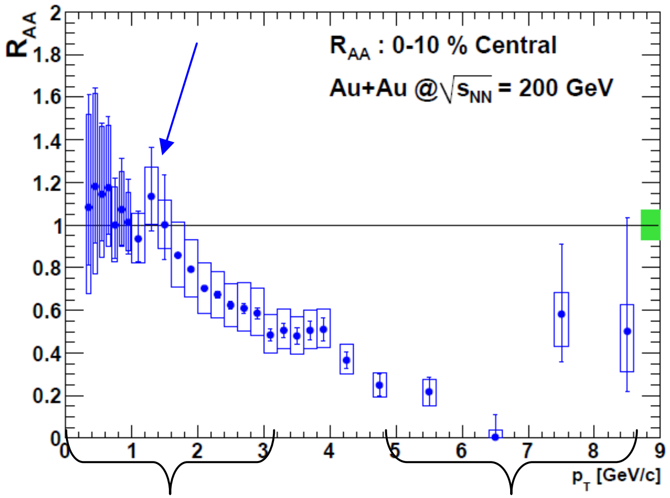
My goal in 20 minutes: at least the lessons *I* have learned from RHIC
and my feelings from LHC

Setting the scene: E-Loss and thermalization

(init) $P_t \approx m_Q$

- Bulk part of Q production
- E gain becomes probable
- HQ scatter and can thermalize with the medium
- very ≠ from light quarks
- *Dominated by collisional processes and diffusion*
- Non perturbative effect (small momentum transfert, coalescence with light quark)
- 1 dominant parameter: D_s

Phenix data

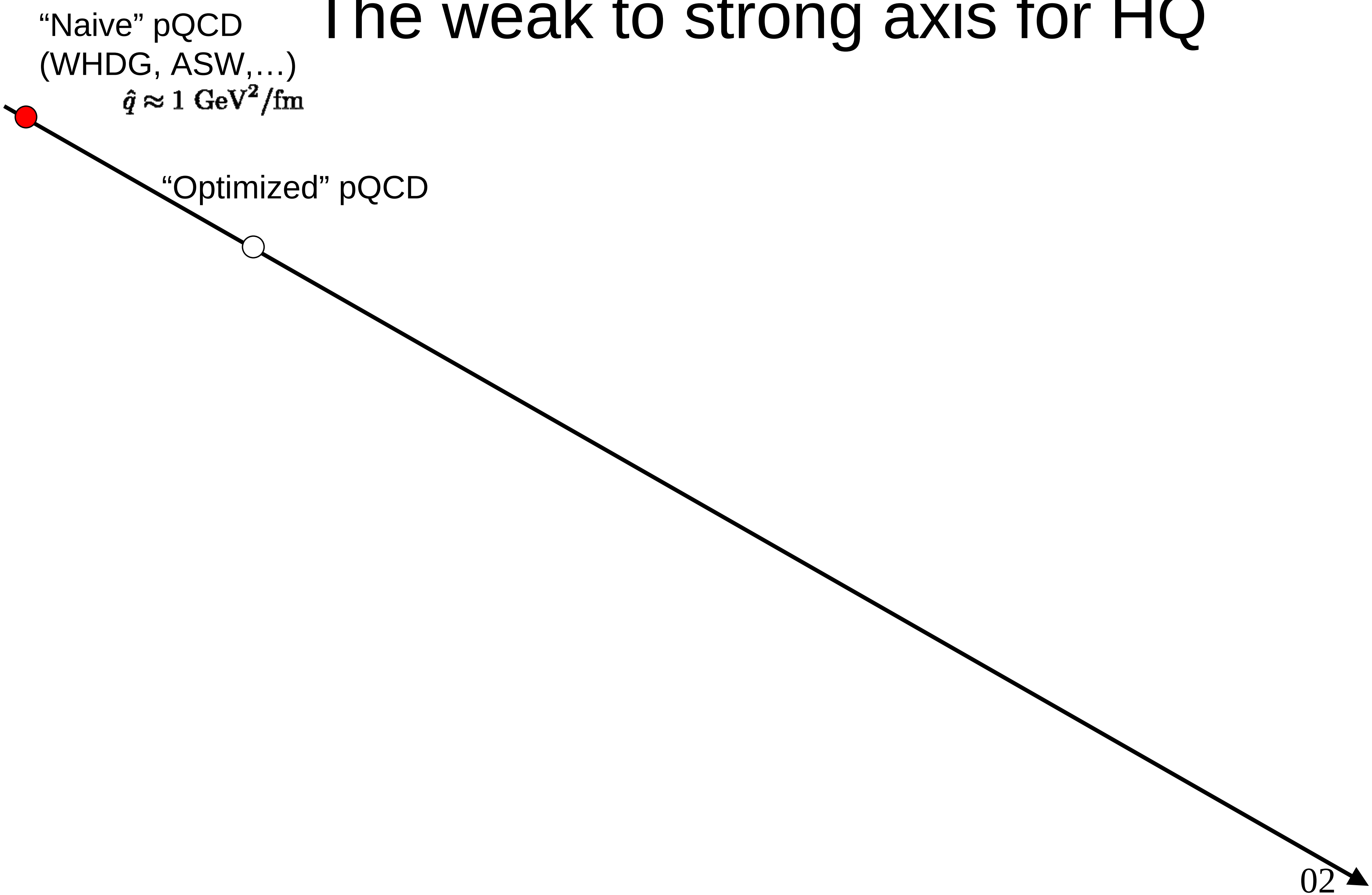


(init) $P_t >> m_Q$

- Rare processes
- Mostly E loss
- HQ go on straight lines and probe the opacity of matter. Little thermalization
- **~ light quarks (s.e.p.)**
- *Coherent radiative + collisional processes*
- Good test of pQCD and eikonal expansion… Theory at work (a priori)
- Several transport coeff implied (dE/dx, B_T,…)

… but one should however avoid do mixing those two worlds !!!

The weak to strong axis for HQ



Fragility and surface emission (light hadrons)

"Once upon a time…": everything comes from the surface => not possible to probe the energy loss in a systematic way

More reasonable picture (Phenix 08: "*Quantitative Constraints on the Transport Properties of Hot Partonic Matter from Semi-Inclusive Single High Transverse Momentum Pion Suppression"*): the models are constrained by 20-25%.

Models and outcome: See S. Bass Talk

TABLE II: Quantitative constraints on the model parameters from the PQM, GLV, WHDG, and ZOWW models and a linear functional form fit.

Model Name	Model Parameter	One Standard Deviation Uncertainty	Two Standard Deviation Uncertainty	Maximum p-value
PQM	$\langle\hat{q}\rangle = 13.2$ GeV^2/fm	+2.1 −3.2	+6.3 −5.2	9.0%
GLV	$dN^g/dy = 1400$	+270 −150	+510 −290	5.5%
WHDG	$dN^g/dy = 1400$	+200 −375	+600 −540	1.3 %
ZOWW	$\epsilon_0 = 1.9$ GeV/fm	+0.2 −0.5	+0.7 −0.6	7.8 %
Linear	b (intercept) = 0.168	+0.033 −0.032	+0.065 −0.066	11.6%
	m (slope) = 0.0017 (c/GeV)	+0.0035 −0.0039	+0.0070 −0.0076	

Challenge

Nevertheless, one has to get the "right" parameter (for instance the transport coefficient) from QCD before claiming one "understands"

A nice interpolation is not an explanation

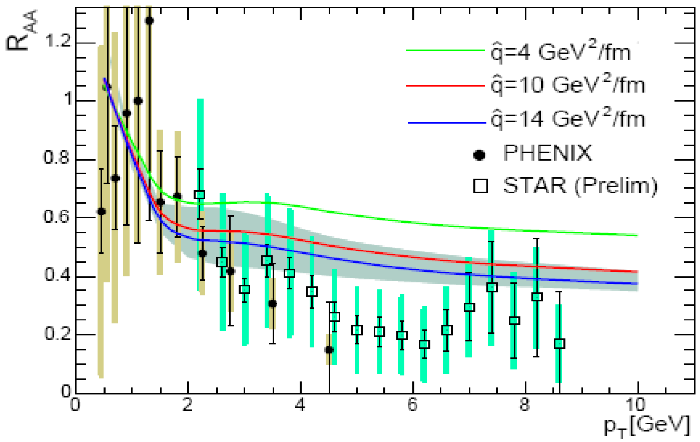
The weak to strong axis for HQ

“Naive” pQCD
(WHDG, ASW,…)
$\hat{q} \approx 1\ \mathrm{GeV^2/fm}$

So-called “Failure of pQCD approach” aka “the non photonic single electron puzzle”

“Optimized” pQCD
(ok with pions)

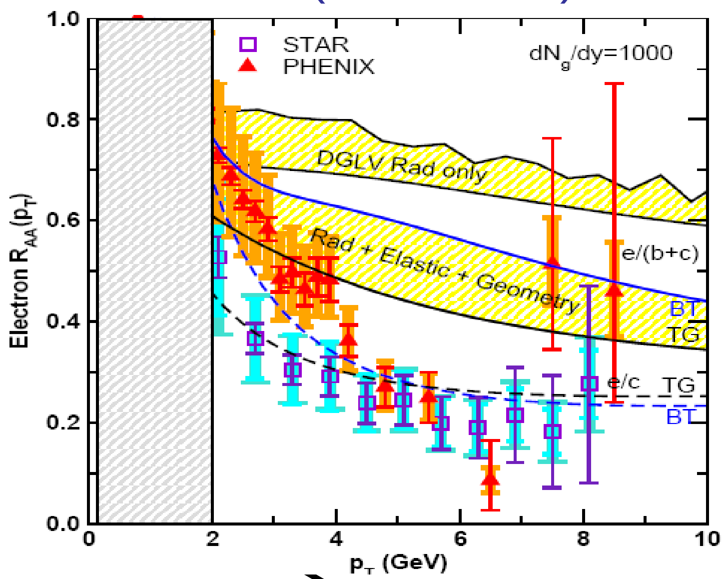
ASW (pure rad. energy loss; extended BDMPS)



Armesto et al Dainese, Phys. Rev D (hep-ph/0501225) & Phys.Lett. B637 (2006) 362-366 hep-ph/0511257

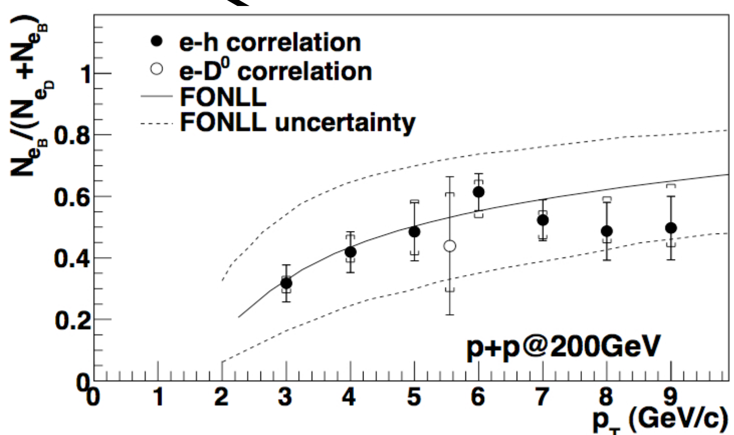
Conclude to rough agreement, subjected to b/c ratio in p-p

coll Eloss (BT and TG) + radiative Eloss



WHDG

Beauty is the problem… but beauty is found to contribute



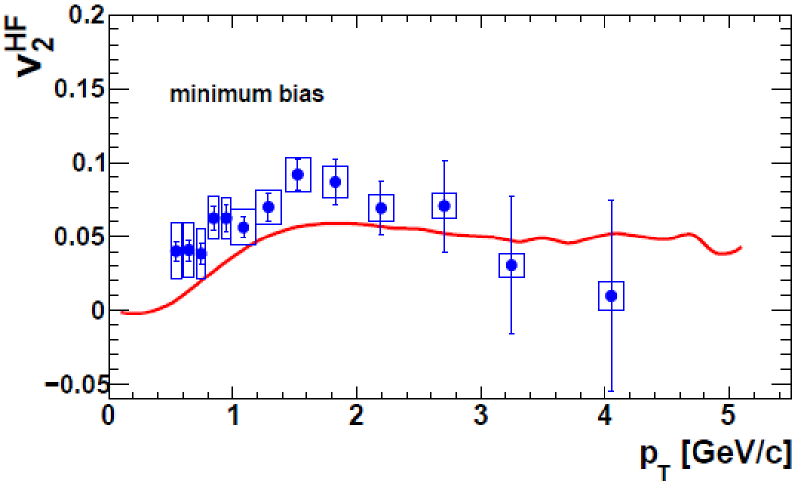
M Aggarwal et al, STAR, PRL 105 202301

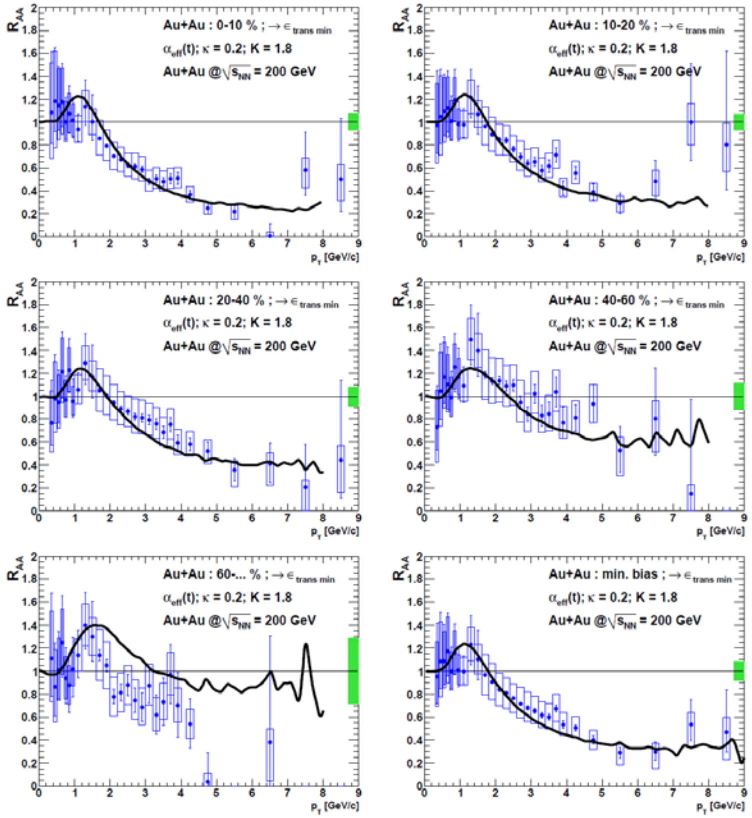
The weak to strong axis for HQ

"Naive" pQCD
(WHDG, ASW,…)
$\hat{q} \approx 1\ \mathrm{GeV^2/fm}$

"Optimized" pQCD

Collisional model with running α_s and optimized gluon propagator (Peshier, Gossiaux and Aichelin, Uphoff)





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"Optimized" pQCD

Running α_s (Peshier, Gossiaux and Aichelin, Uphoff)

Distorsion of heavy meson fragmentation functions due to the existence of bound mesons in QGP, R. Sharma, I. Vitev & B-W Zhang 0904.0032v1 [hep-ph]

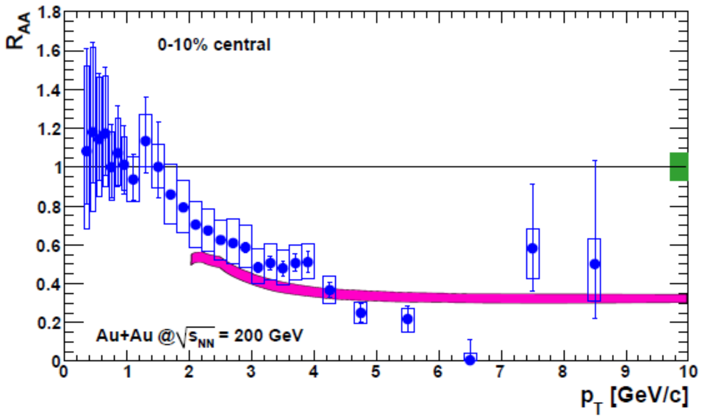

FIG. 41: (Color online) R_{AuAu} in 0–10% centrality class compared with a collisional dissociation model [78] (band) in Au+Au collisions.

The weak to strong axis for HQ

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(WHDG, ASW,…)
$\hat{q} \approx 1\ \mathrm{GeV}^2/\mathrm{fm}$

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Distorsion
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R. Sharma
0904.0032

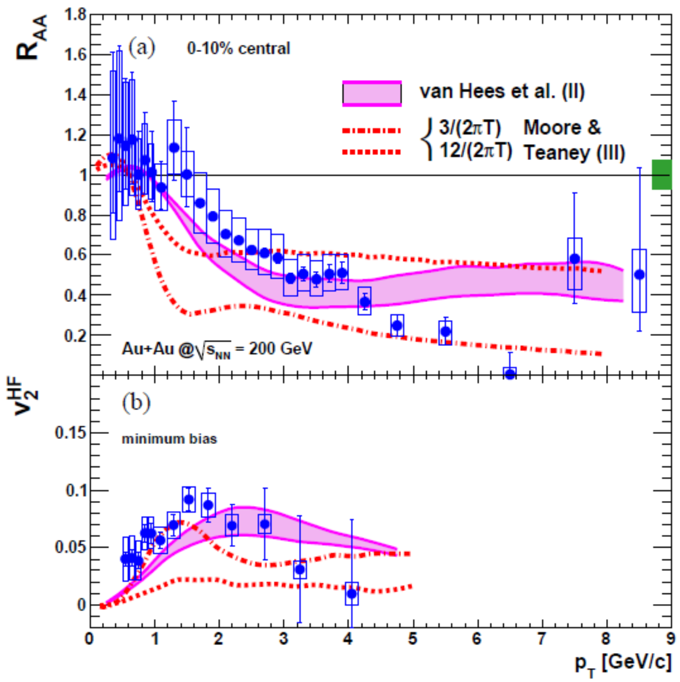

FIG. 40: (Color online) Comparison of Langevin-based models from [74–76] to the heavy flavor electron R_{AuAu} for 0–10% centrality and v_2 for minimum-bias collisions.

Bound states diffusion or non-perturbative, lattice potential scattering models (see R. Rapp and H Van Hees 0903.1096 [hep-ph] for a review)

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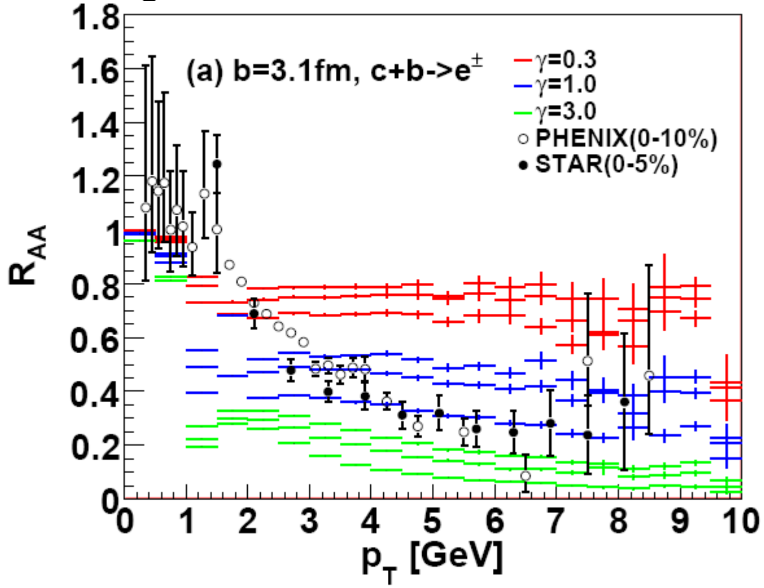


ADS/CFT
(akamatsu et al)

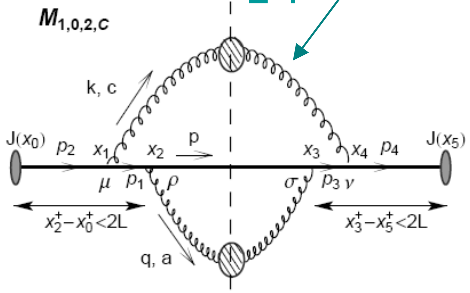
The weak to strong axis for HQ

"Naive" pQCD
(WHDG, ASW,…)
$\hat{q} \approx 1\ \mathrm{GeV}^2/\mathrm{fm}$

"Optimized" pQCD

Beyond the static scatterer limit: M. Djordjevic, Preprint arXiv:0903.4591 [nucl-th] (2009) and previous work with U. Heinz

HTL for x not << 1 ?



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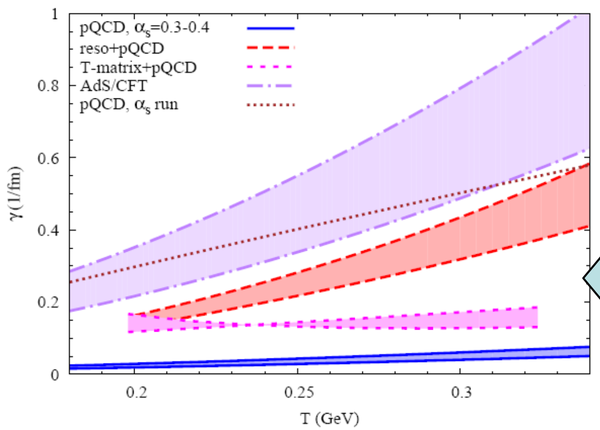
Non perturbative equivalent for g+Q ?
No radiative !



from Rapp & Van Hees 0903.1096

Lesson n°1:

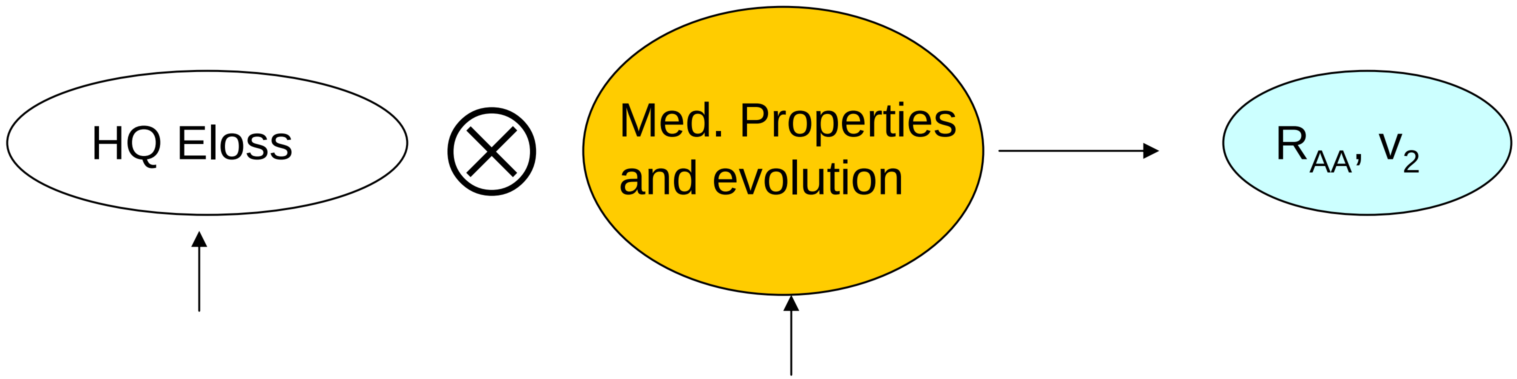
Several models containing either non pertubative features or tunable parameter are able to reproduce the HQ data, but many questions remain… and how to reconcile them all stays a challenge

ADS/CFT
(akamatsu et al)

09

Questions

Q1: Does HQ Eloss really allows to probe the system, or more a subject of study in itself ?



Convolution Kernel ?
Object of interest ?

Object of interest ?
Convolution Kernel ?

Q2: To make progress: decipher the most “correct” model/theory for Eloss:

- Various path length dependences: $\Delta E \propto L, L^2, L^3$,
- Various energy dependences: $\Delta E(E)$
- Various mass dependences: $\Delta E(M)$

From comparison with data: Not a clear view emerging for HQ… simply due to the convolution devil ? Some kind of fragility ?

Q3: The role of LHC ?

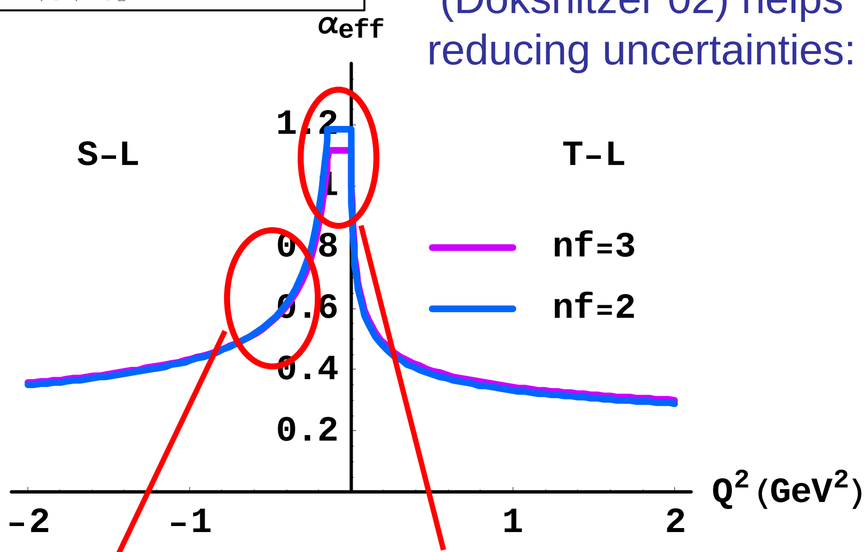
The (P).G.A. approach

Motivation: Even a fast parton with the largest momentum P will undergo collisions with moderate q exchange and large $\alpha_s(Q^2)$. The running aspect of the coupling constant has been "forgotten/neglected" in most of approaches

Effective $\alpha_s(Q^2)$ (Dokshitzer 95, Brodsky 02)

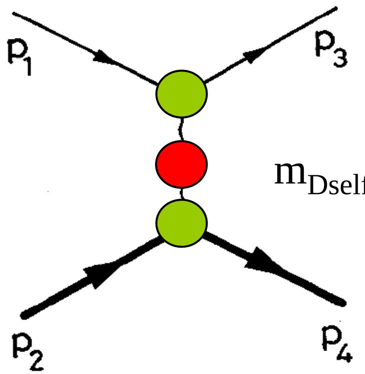
$$\frac{1}{Q_u}\int_{|Q^2|\leq Q_u^2} dQ\,\alpha_s(Q^2) \approx 0.5$$

"Universality constrain" (Dokshitzer 02) helps reducing uncertainties:



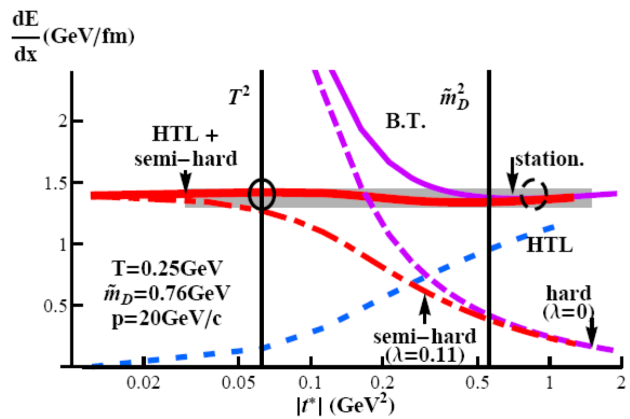
IR safe. Q^2 close to 0 does not contribute to Eloss

Large values for intermediate momentum-transfer => larger cross section



$$m_{Dself}^2(T) = (1+n_f/6)\, 4\pi\alpha_{eff}(m_{Dself}^2)\, T^2$$

One gluon exchange effective propagator, designed in order to guarantee maximal insensitivity of dE/dx in Braaten-Thomas scheme

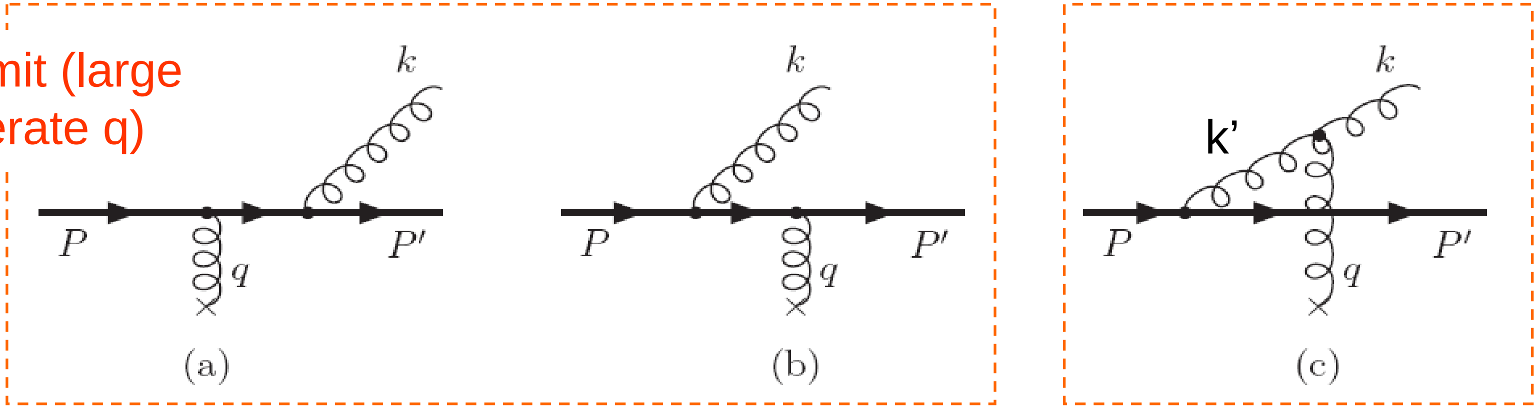


A model; not a renormalizable theory

Basic radiation:(massive) Gunion-Bertsch

Radiation α deflection of current (semi-classical picture)

Eikonal limit (large E, moderate q)



Dominates as small x as one “just” has to scatter off the virtual gluon k’

$$\omega \frac{d^3\sigma_{\rm rad}^{x\ll 1}}{d\omega d^2k_\perp dq_\perp^2} = \frac{N_c\alpha_s}{\pi^2}(1-x) \times \frac{J_{\rm QCD}^2}{\omega^2} \times \frac{d\sigma_{\rm el}^{Qq}}{dq_\perp^2}$$

with

$$\frac{J_{\rm QCD}^2}{\omega^2} = \left(\frac{\vec{k}_\perp}{k_\perp^2 + x^2M^2 + (1-x)m_g^2} - \frac{\vec{k}_\perp - \vec{q}_\perp}{\left(\vec{k}_\perp - \vec{q}_\perp\right)^2 + x^2M^2 + (1-x)m_g^2} \right)^2$$

Gluon thermal mass ~2T (phenomenological; not in BDMPS)

Quark mass

Both cures the colinear divergences and will influence the radiation spectra

Radiation spectra

$$\omega \frac{d^2\sigma^{x\ll 1}_{\mathrm{rad}\,''\mathrm{QCD}''}}{d\omega dq_\perp^2} \approx \frac{2N_c\alpha_s}{\pi} \ln\left(1 + \frac{q_\perp^2}{3\tilde{m}_g^2}\right) \times \frac{d\sigma_{\mathrm{el}}^{Qq}}{dq_\perp^2}$$

… to convolute with your favorite elastic cross section

$$\tilde{m}_g^2 = (1-x)m_g^2 + x^2 M^2$$

If typical $q_\perp \approx T$:

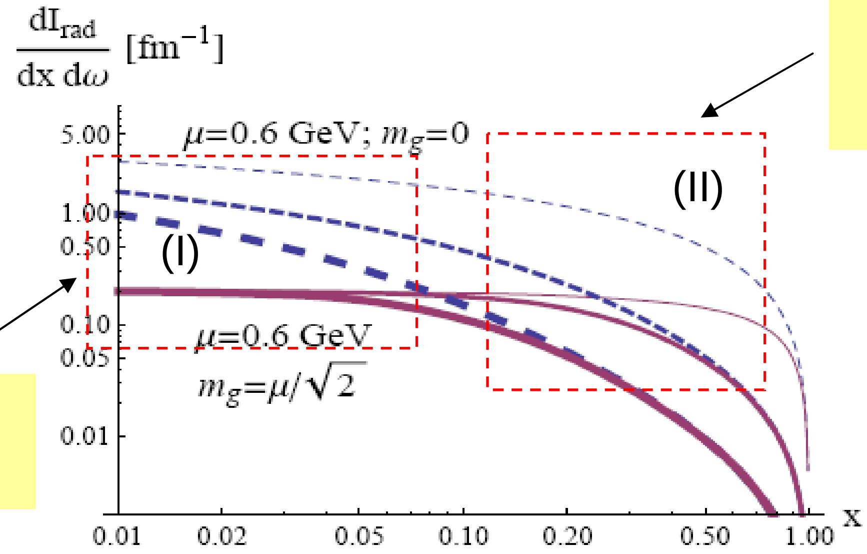
$$\frac{d^2 I_{\mathrm{GB}}^{x\ll 1}}{dz\, d\omega} \sim \frac{2N_c\alpha_s}{3\pi} \times \frac{1}{m_g^2 + x^2 M^2} \times \underbrace{\frac{\langle q_\perp^2\rangle}{\lambda}}_{\hat{q}}$$

For coulomb scattering:

Light quark

c-quark

b-quark



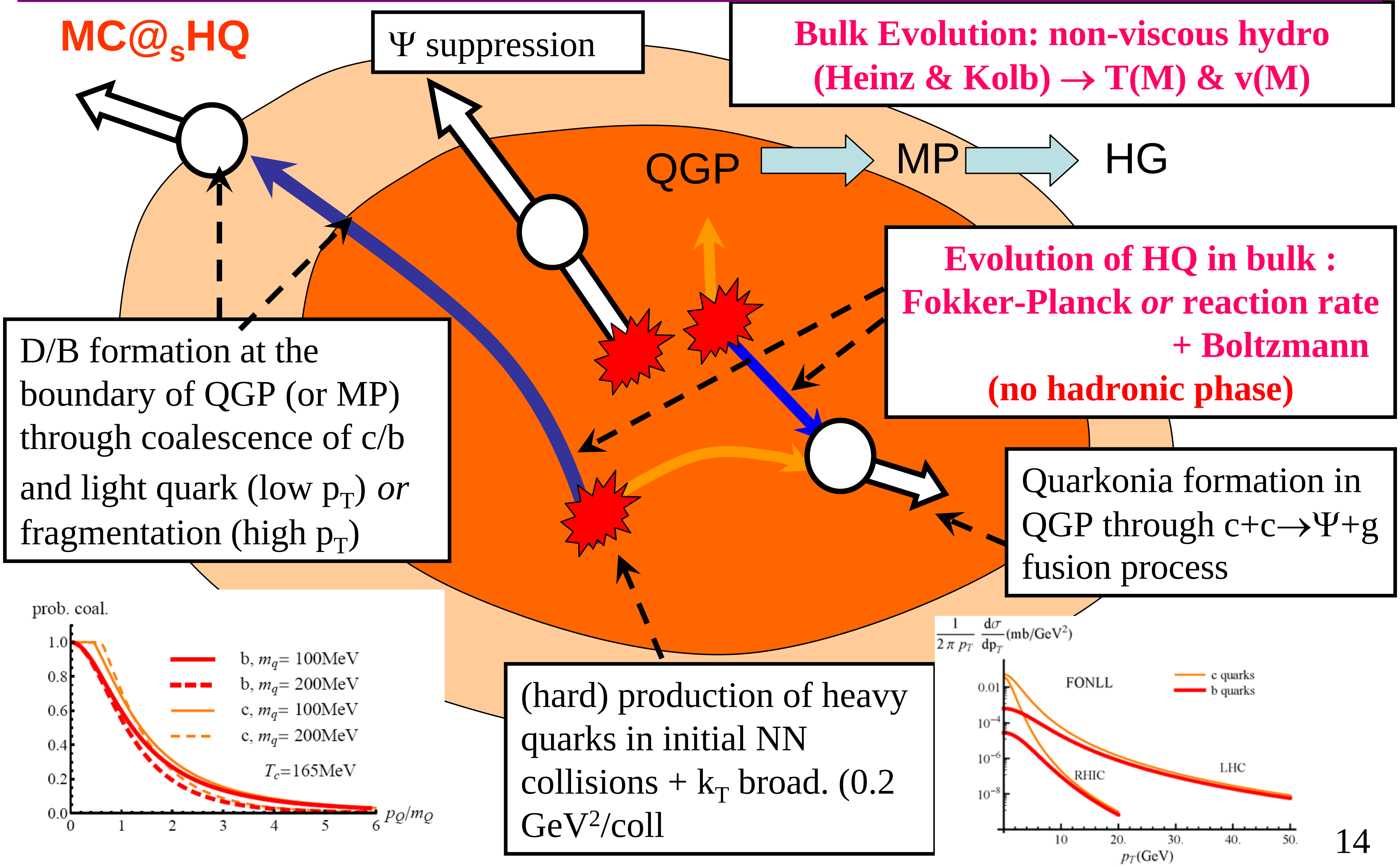
Strong dead cone effect for $x>m_g/M_Q$ (mass hierarchy)

Little mass dependence (especially from $q\rightarrow c$)

2010 J. Phys. G: Nucl. Part. Phys. 37 094019

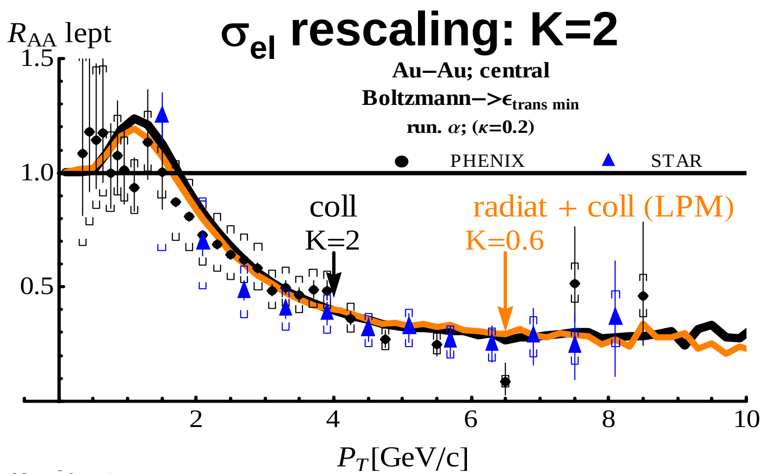
Thermal gluon mass helps towards solving single electron problem

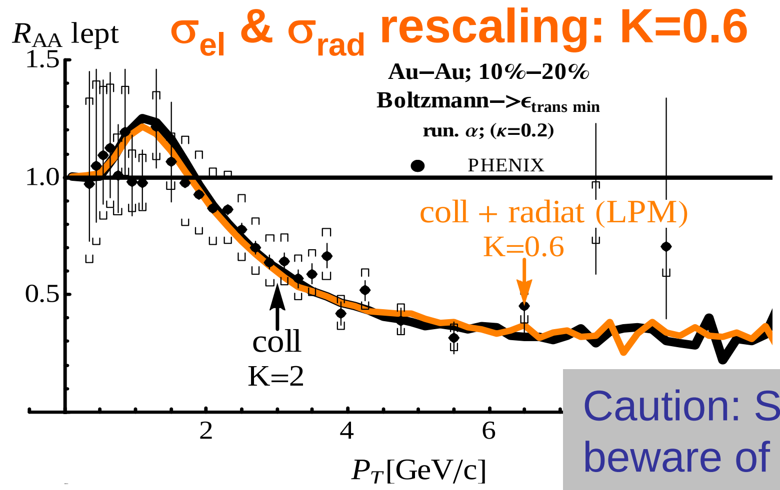
Schematic view of « Monte Carlo @ Heavy Quark » generator



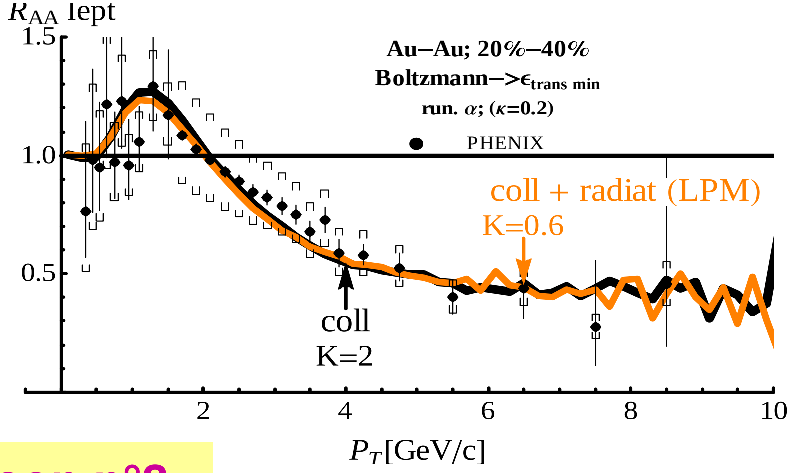
Collisional vs {Radiative + Coll} for leptons @ RHIC

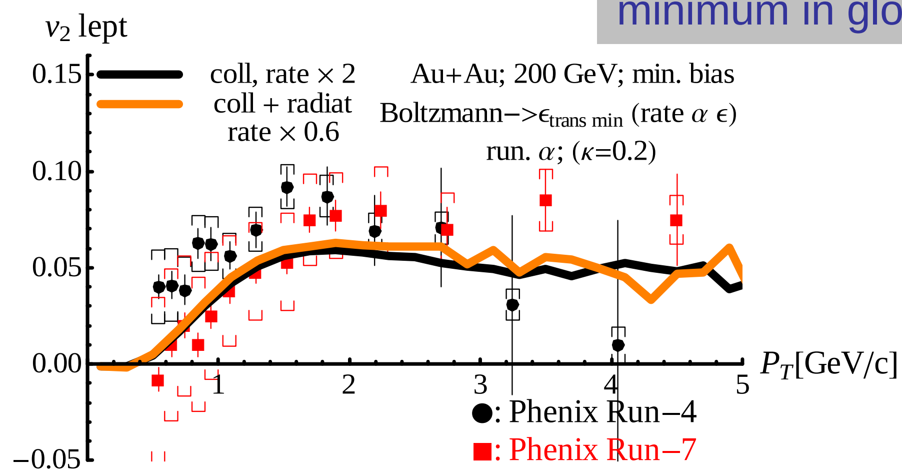
Coll. and rad. Eloss exhibit very different energy and mass dependence. However…





Caution: Steffen: beware of shallow minimum in global fit !





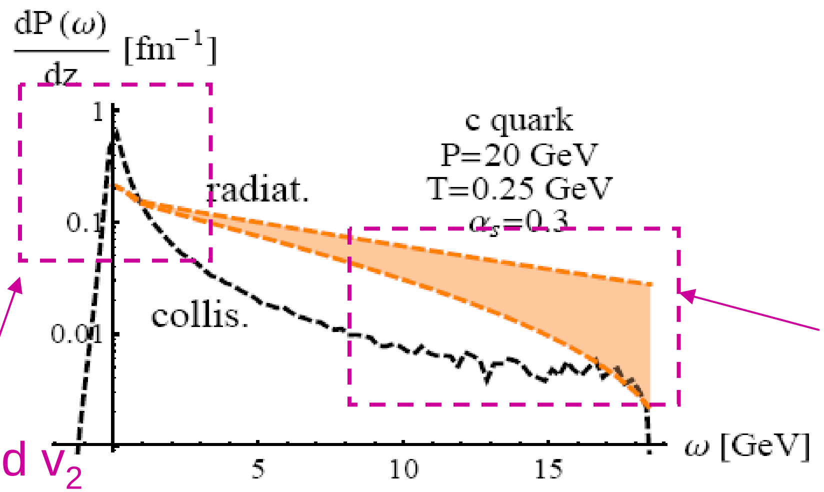
Lesson n°2:

One “explains” it all with ΔE α L (for HQ)

RHIC data cannot decipher between the 2 local microscopic E-loss scenarios; **WHY ?**

Interpretation

The heavy-quark physics at play for RHIC measured up to now (R_{AA} and v_2) is known (Baier 2001) to be governed by the radiation of multiple small energy gluons… and in general by the probability of energy loss at small ΔE.



R_{AA} and v_2 physics

Explains why so many models "explain"the data *even at the largest* p_T at RHIC provided they get the proper weight

What we need

- D and B separately (in any case)
- tagged HQ jets and other correlations)

Bad control on the theory

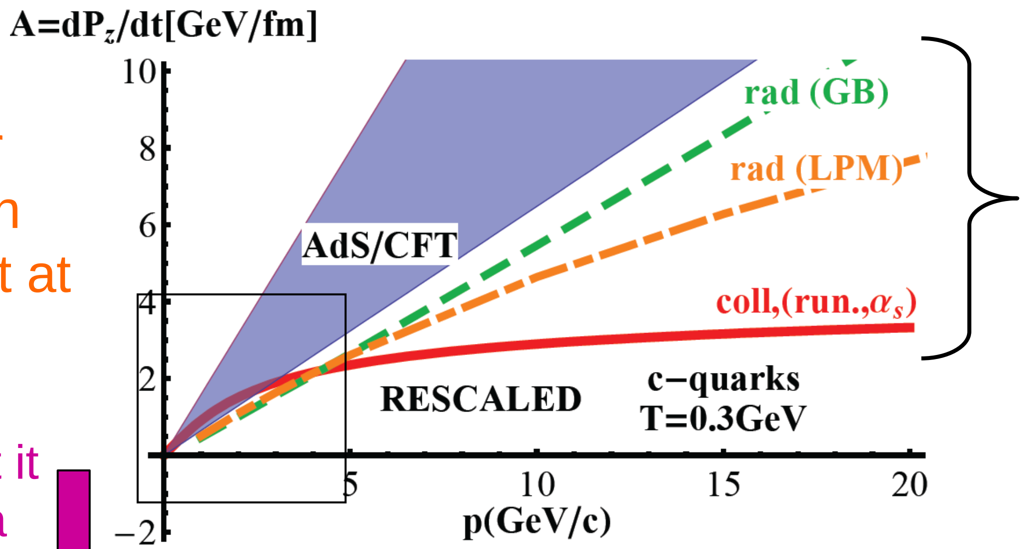
In our view, it is nevertheless more plausible to describe the physics in terms of a rather strong collisional energy loss supplied with an even stronger radiative energy loss (at least for γ ">>" 1).

Fokker Planck is in the place !

QGP properties: update on stopping power

Gathering all *rescaled* models (*coll. and radiative*) compatible with RHIC R_{AA}:

Similar diffusion coefficient at low p



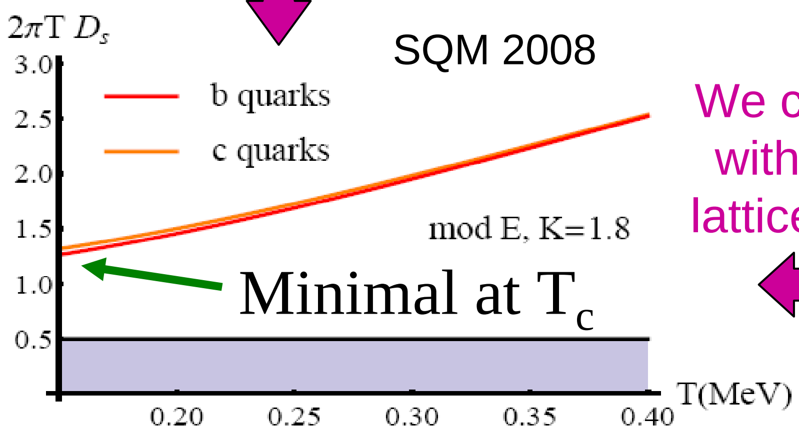
Present RHIC experiments cannot resolve between those various trends

quite consistent as the drag coefficient reflects the average momentum loss (per unit time) => large weight on x ~ 1

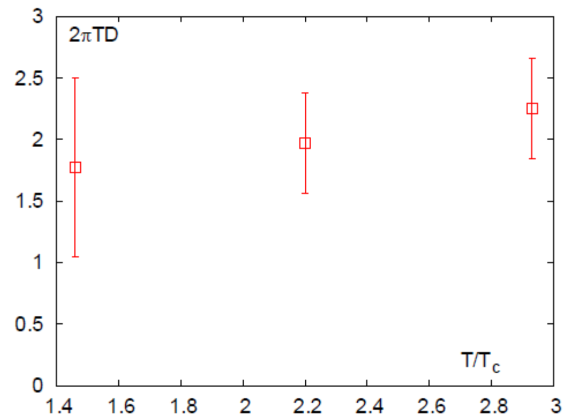
Hope that LHC will do !!!

We extract it from data

SQM 2008



We compare with recent lattice results



Kaczmarek
Bad Honnef
2011

Lesson n°3: Yes, it is really possible to reveal some fundamental property of QGP using HQ probes

The power of Fokker-Planck

Inspired by these feature or following the idea that some heavy quark would need many collisions for significant deflection….

2004: Gossiaux, Guiho &, Aichelin (J.Phys. G31 (2005) S1079-S1082, arXiv:hep-ph/0411324)

Van Hees & Rapp

Moore & Teaney

→ 2008: Akamatsu, Hatsuda & Hirano

→ 2011: Alberico et al.

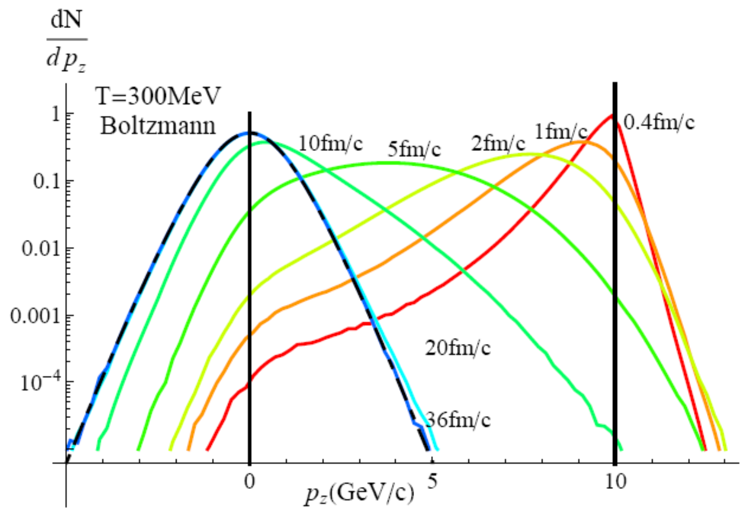
Cao & Bass

However:

- No proof from statistical physics that a heavy *relativistic* particle should follow Brownian motion.

- Indeed, cases where *it does not !*

Boltzmann evolution of a statistical ensemble of c quarks in a uniform QGP, peaked at 10 GeV/c at initial time →



No gaussian behavior found, except at later times !!!

Those deviation from Brownian motion are not seeable in the RAA observable but could show up in more exclusive observables !

A lot of Eloss approaches do not proceed through a direct numerical implementation of microscopic interactions with the medium… but nevertheless neglect those large fluctuations in evaluating $\mathcal{P}(\Delta E)$!!!

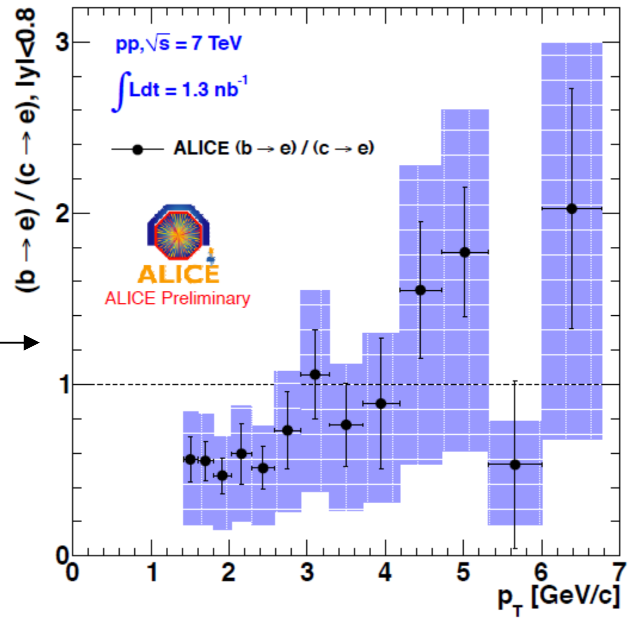
Feelings from early LHC

The ultimate deciphering machine:

Exclusive D mesons !!! (ALICE)

B mesons ? Non-prompt J/Ψ from B decay (CMS)

Electrons and muons (additional uncertainty: c/b cockail) →



… but of course **very** preliminary

From Kweon
(Bad Honnef 2001)

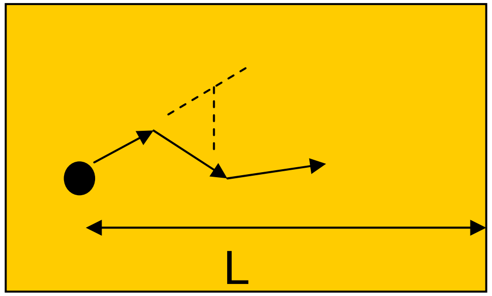
Parametric dependences in the realm of LHC

LHC: the realm for coherence !

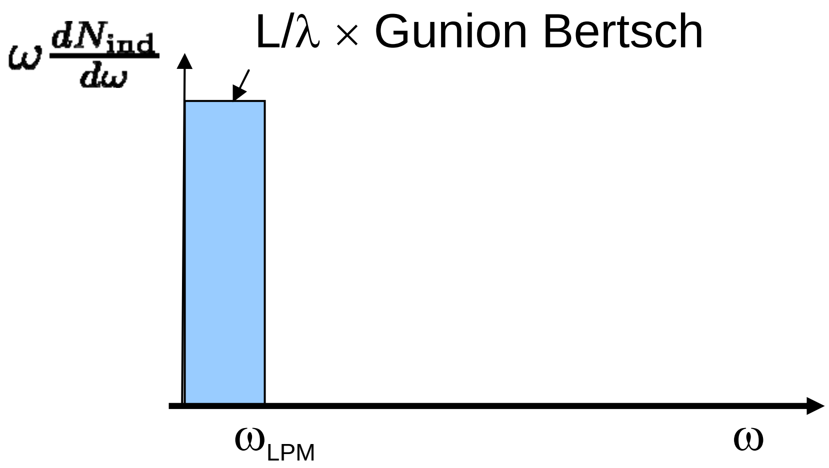
Application for radiative energy loss in the eikonal limit

I: vs path length L (light q)

3 regimes:



QGP brick



→ a) Low energy gluons: Typical formation time ω/k_t^2 is smaller than mean free path λ:

$\omega < \omega_{LPM} := \frac{\hat{q}\lambda^2}{2}$ Incoherent Gunion-Bertsch radiation

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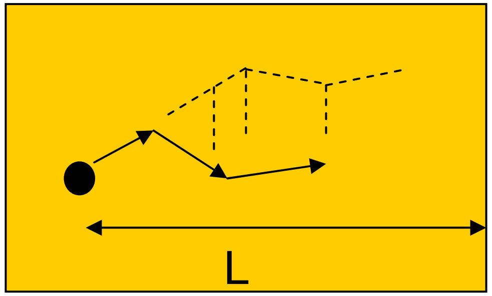

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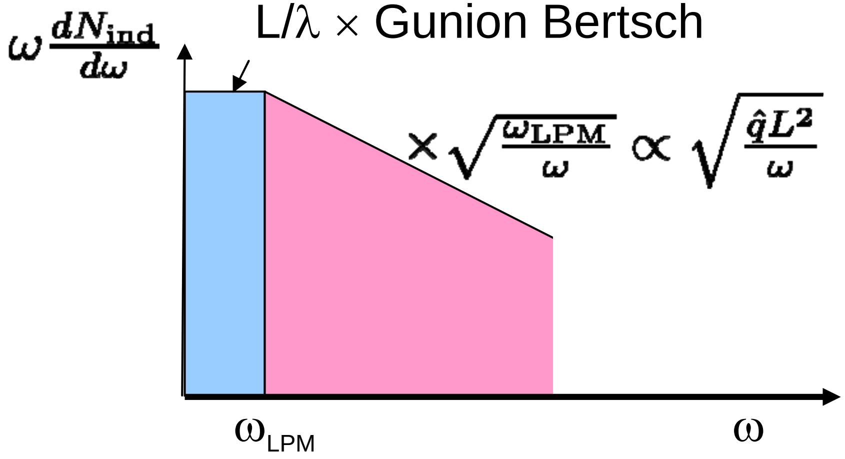

a) Low energy gluons: Typical formation time ω/k_t^2 is smaller than mean free path λ:

$\omega < \omega_{LPM} := \frac{\hat{q}\lambda^2}{2}$ **Incoherent** Gunion-Bertsch radiation

→ b) Inter. energy gluons: Produced **coherenty** on N_{coh} centers after typical formation time $t_f = \sqrt{\frac{\omega}{\hat{q}}} \Rightarrow N_{coh} = \frac{t_f}{\lambda} = \sqrt{\frac{\omega}{\omega_{LPM}}}$ leading to an effective reduction of the GB radiation spectrum by a factor $1/N_{coh}$

Parametric dependences in the realm of LHC

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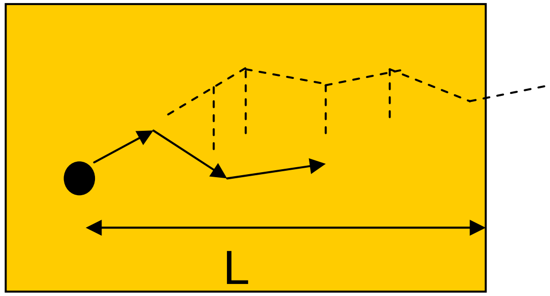
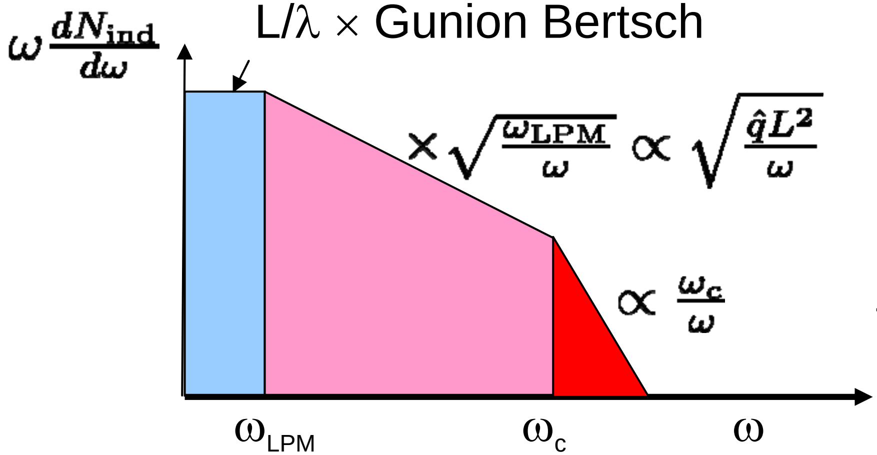


QGP brick



GLV (2001), Zakharov (2001)

a) Low energy gluons: **Incoherent** Gunion-Bertsch radiation

b) Inter. energy gluons: Produced **coherenty** on N_{coh} centers after typical formation time $t_f = \sqrt{\frac{\omega}{\hat{q}}}$

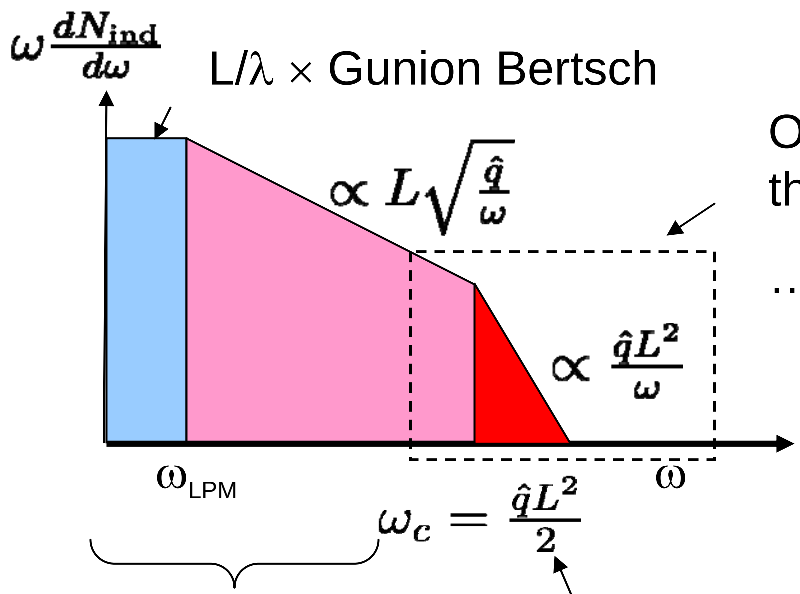
→ c) High energy gluons: $\sqrt{\frac{\omega}{\hat{q}}} > L \Rightarrow \omega > \omega_c := \frac{\hat{q}L^2}{2}$ Produced mostly outside the QGP… nearly as in vacuum **do not contribute significantly to the induced energy loss**

Parametric dependences in the realm of LHC

LHC: the realm for coherence !

Application for radiative energy loss in the eikonal limit

I: vs path length L (light q)



Only this tail makes the L^2 dependence in the average Eloss integral …

…provided the higher boundary ω=E > ω_c.

Otherwise, everything α L

Bulk part of the spectrum still scales like path length L

Concrete values @ LHC $\begin{cases} \hat{q} \sim 25\text{GeV}^2/\text{fm} \\ L \sim 2\text{fm} \end{cases}$

$\omega_c \sim 500\text{GeV}$ Huge value !

Personal opinion: a large part of radiative energy loss @ LHC still scales like the path length

Parametric dependences in the realm of LHC

II: vs mass (by increasing complexity)

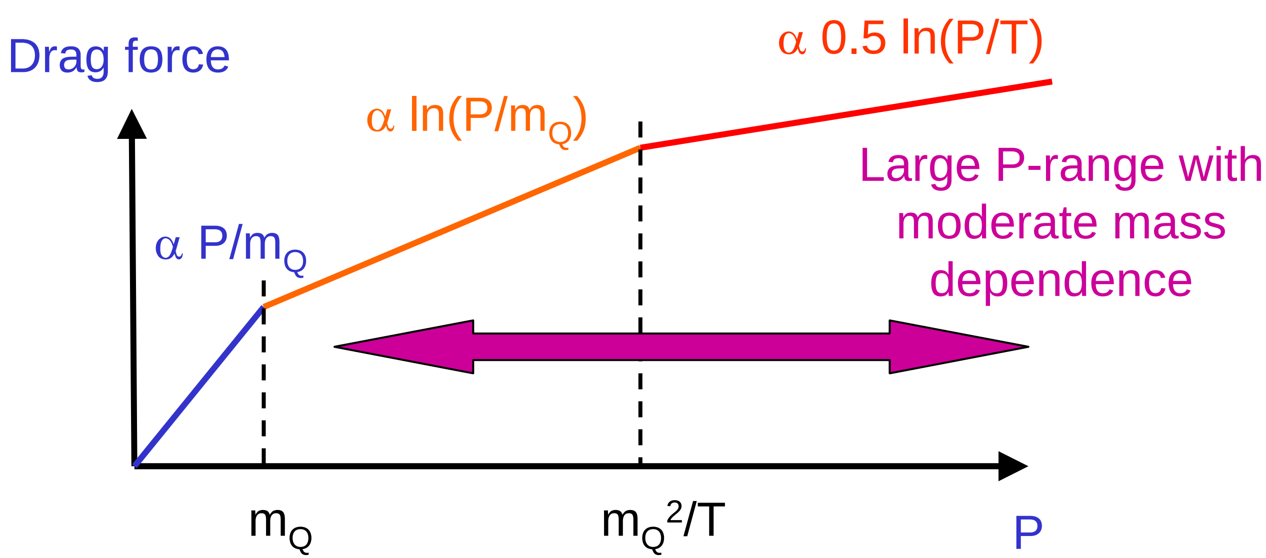
a. <u>AdS/CFT:</u> Various results from our holographic friends (trailing string):

Drag coefficient →

Pretty strong $1/m_Q$ dependence on the mass

coefficient	$v \approx 0$	ref.	finite v	ref.
$\eta_D := \frac{A}{p}$	$\frac{\pi\sqrt{\lambda}T_{\rm sym}^2}{2m_Q}$	[Cas06]	$\frac{\pi\sqrt{\lambda}T_{\rm sym}^2}{2m_Q}$	[Her06, Gub06]
$\kappa_T = 2B_T = \frac{\hat{q}}{2}$	$\pi\sqrt{\lambda}T_{\rm sym}^3$	[Cas06]	$\pi\sqrt{\lambda}T_{\rm sym}^3\gamma^{\frac{1}{2}}$	[Cas07, Gub08]
$\kappa_L = 2B_L$	"		$\pi\sqrt{\lambda}T_{\rm sym}^3\gamma^{\frac{5}{2}}$	[Gub08]

b. <u>Collisional E loss:</u>



Parametric dependences in the realm of LHC

c. <u>Radiative E loss</u>

Large variety of regimes depending on:

For a review: Peigné & Smilga 2008

- Particle energy E
- Path length L
- Production point ($-\infty$ or in QGP)
- Opacity (# of collisions L/λ)

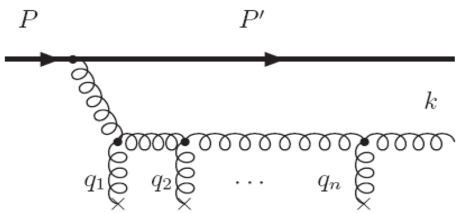
Driving concepts:

1) Gluons stemming from HQ have smaller formation time

$$l_{f,\mathrm{sing}} \approx \frac{2x(1-x)E}{m_g^2 + \boxed{x^2 M^2}}$$

2) Gluon radiation on several scatterers:

Less affected by coherence effect



decoherence phase ≈ 1

$$l_{f,\mathrm{mult}}(Q+g) = \frac{2\omega\boxed{\Phi_{\mathrm{dec}}}}{\sqrt{\omega\hat{q}\Phi_{\mathrm{dec}} + \left(\frac{M^2\omega^2}{2E^2}\right)^2} + \frac{M^2\omega^2}{2E^2}}$$

Special case: $\lambda < \boxed{l_{f,\mathrm{mult}} < L^{\star\star}_{\mathrm{QCD}}} := \frac{m_g^2 + x^2M^2}{\hat{q}}$ Basic practical criteria

One has a possibly large coherence number $N_{coh} := l_{f,mult}/\lambda$ but the GB radiation spectrum stays ROBUST

Radiation on an effective center of length $l_{f,mult} = N_{coh}\,\lambda$ → $\frac{d^2 I}{dz\, d\omega}$

Radiation at small angle $\propto \langle Q_\perp^2 \rangle$ i.e. $\propto N_{coh}$

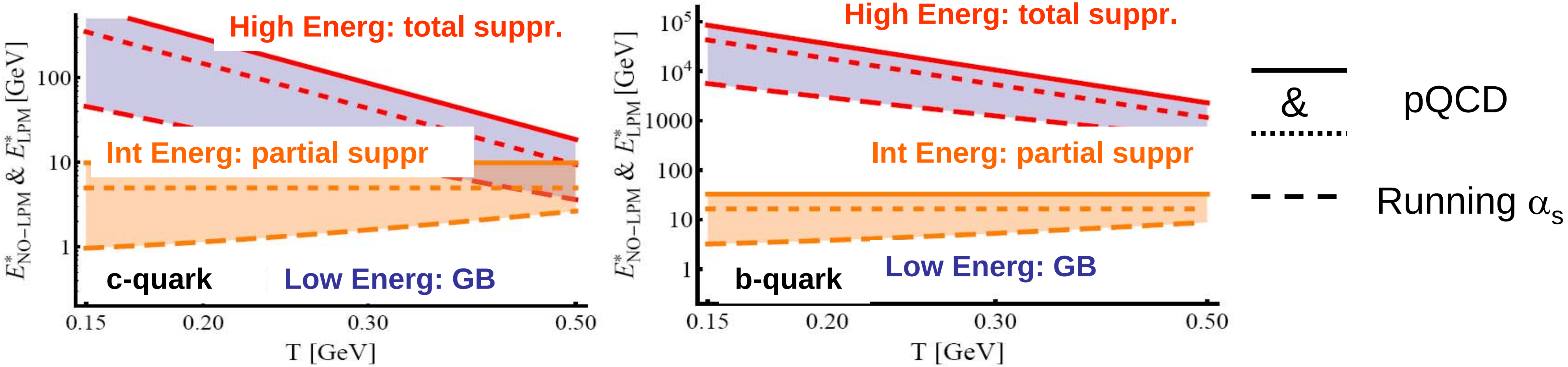
Compensation at leading order !

Regimes in radiation spectra

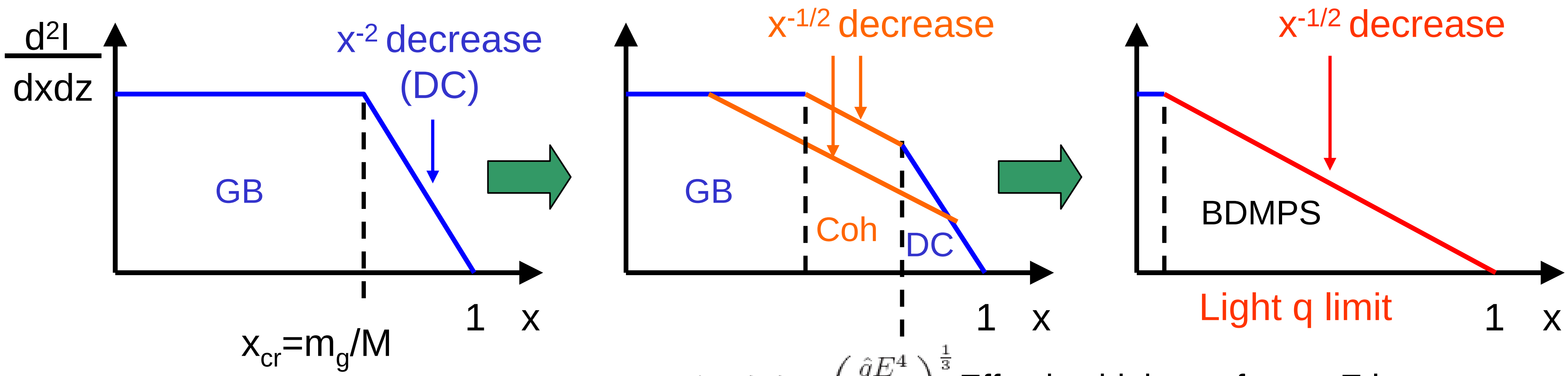
Working out the basic criteria

3) Hierarchy of scales: $\underbrace{E_{\rm LPM}(q)}_{T} \ll \underbrace{E^{\star}_{\rm NO-LPM}(Q)}_{\frac{M}{g_s T}\times T} \ll \underbrace{E^{\star}_{\rm LPM}(Q)}_{\left(\frac{M}{g_s T}\right)^4 \times T}$

larger mass ⇒ Less coherence effects



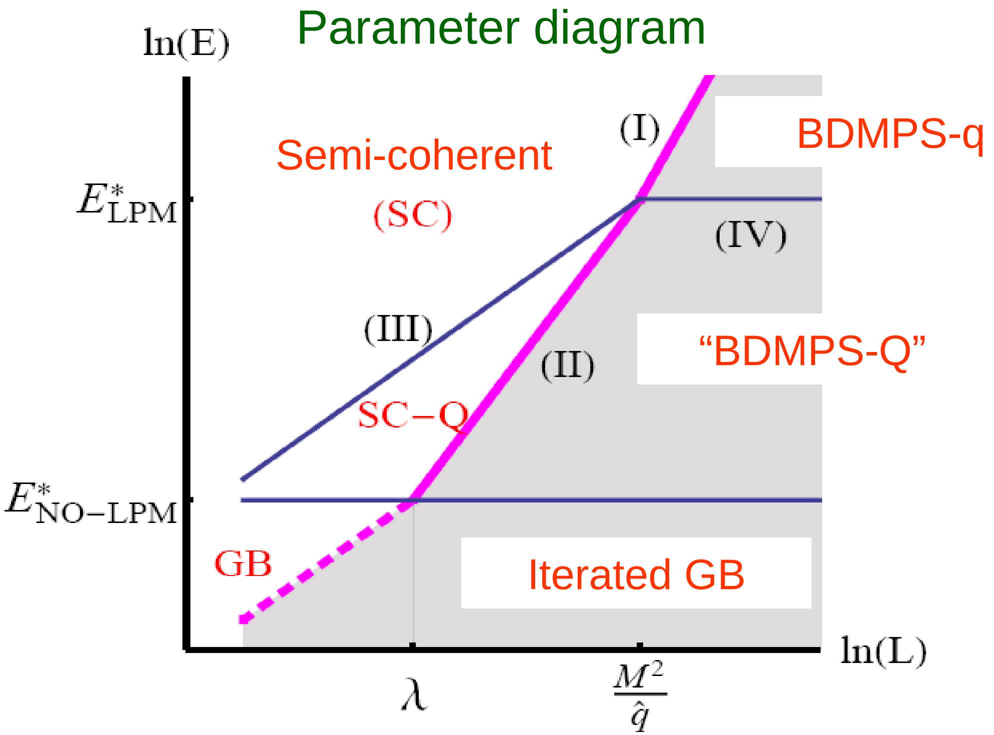
4) Spectra



$\omega^{\star}_{\rm LPM}(E) = \left(\frac{\hat{q}E^4}{2M^4}\right)^{\frac{1}{3}}$ Effective higher ω for av. E loss

Regimes in radiation spectra

5) More regimes for finite path length:



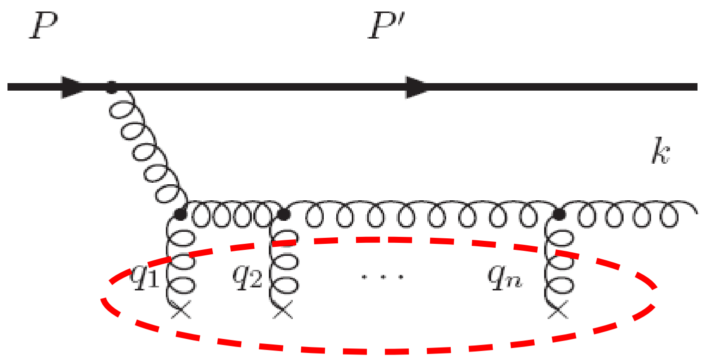
No mass dependence

$1/M^{0<a<1}$ or ln(..;/M) mass dependence

1/M mass dependence

As I am not aware of a tractable theory that encompass all those regimes…

…My own semi-quantitative model:



For $l_{f,mult} > \lambda$, gluon is radiated coherently on a distance $l_{f,mult}$

Model: all scatterers acts as a single effective one with probability $p_{Ncoh}(Q_\perp)$ obtained by convoluting individual probability of kicks

$$\left(\frac{d^2 I^{x\ll 1}_{\text{“QCD”}}}{dz\, d\omega}\right)_{\text{coh}} \approx \frac{2N_c\alpha_s}{\pi l_{f,\text{mult}}}\left\langle \ln\left(1+\frac{Q_\perp^2}{3\tilde{m}_g^2}\right)\right\rangle_{p_{N_{\text{coh}}}}$$

with

$$\tilde{m}_g^2 \approx m_g^2 + x^2 M^2 + \sqrt{\frac{\hat{q}\omega}{\Phi_{\text{dec}}}}$$

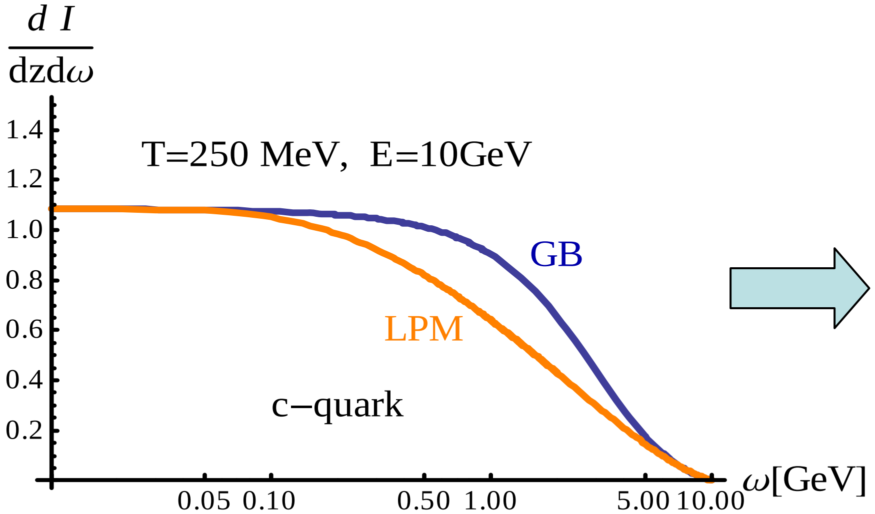
Prevents radiation of gluon of formation time > $l_{f,mult}$

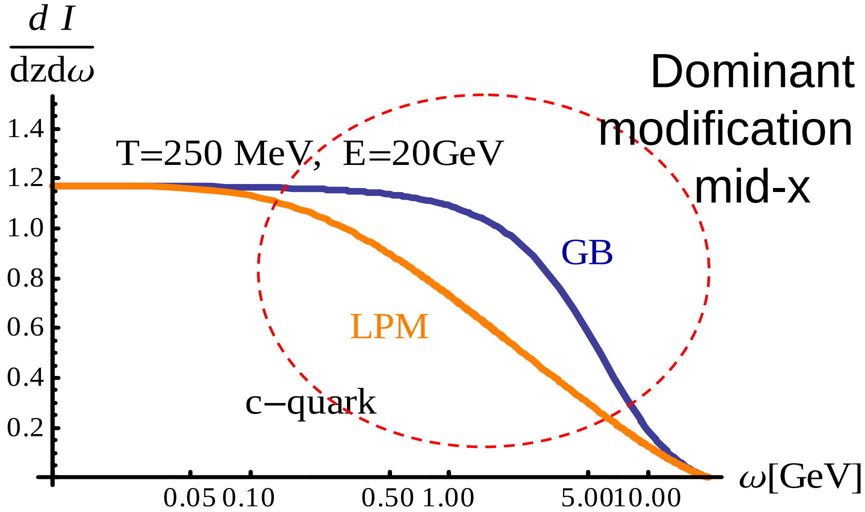
After averaging:

$$\frac{d^2 I_{\text{eff}}}{dz\, d\omega} \sim \frac{\alpha_s}{N_{\text{coh}}\tilde{\lambda}} \ln\left(1+\frac{N_{\text{coh}}\mu^2}{3\left(m_g^2 + x^2 M^2 + \sqrt{\omega\hat{q}}\right)}\right)$$

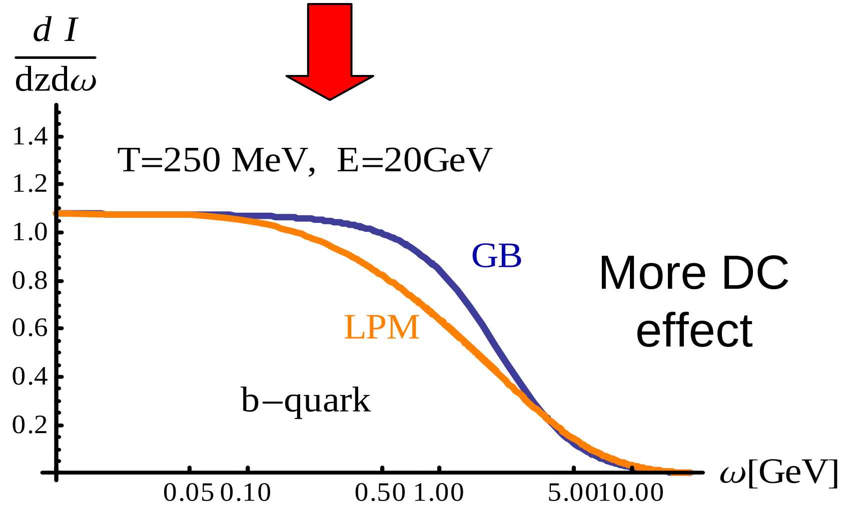
- Compares well to the BDMPS result ($N_{coh} \gg 1$) for light quark (up to some color factor => rescaling), including the coulombian logs.
- Naturally interpolates to the massive-GB regime for $N_{coh} \leqslant 1$.
- Incorporates all regimes discussed above.

Reduced spectra from coherence





Dominant modification at mid-x



More DC effect

: Suppression due to coherence increases with increasing energy

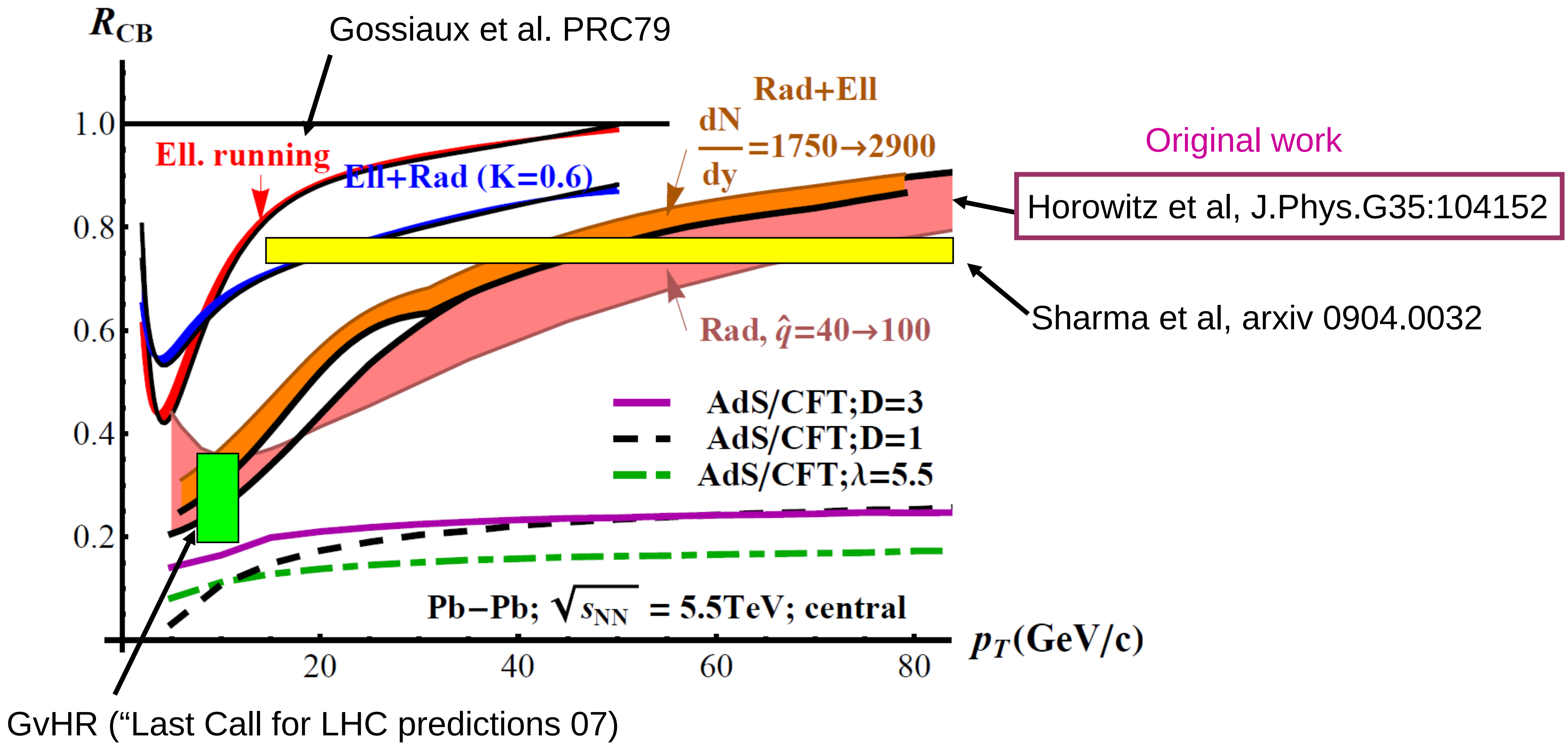
: Suppression due to coherence decreases with increasing mass

In (first) Monte Carlo implementation: we quench the probability of gluon radiation by the ratio of coherent spectrum / GB spectrum

No significant effect seen at RHIC

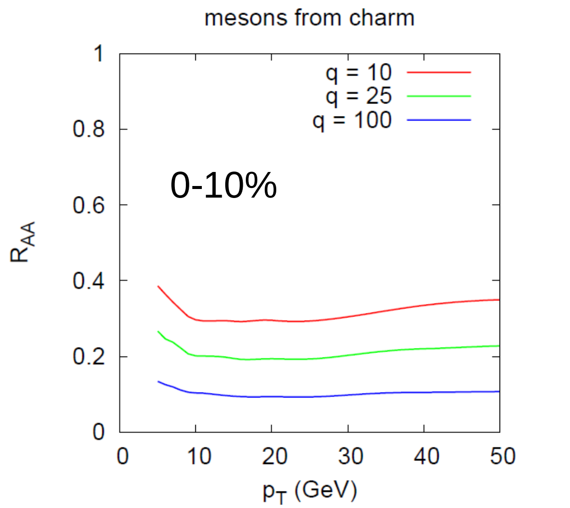
Resolving mass dependences @ LHC: b vs c

A while ago $R_{C/B} = R_{AA}(C)/R_{AA}(B)$ as a deciphering observable; good, as many of the unknowns factor out (e.g. the opacity, the medium evolution)

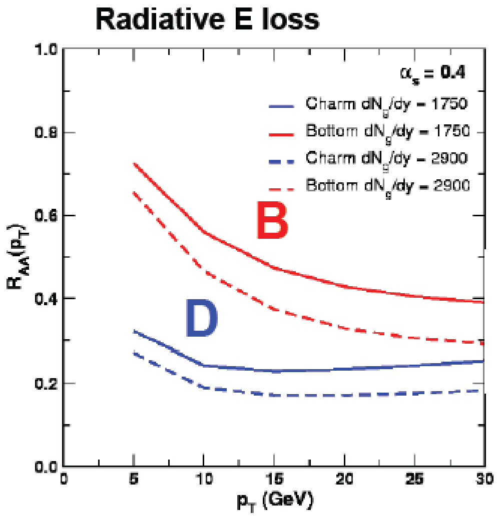


Charming LHC

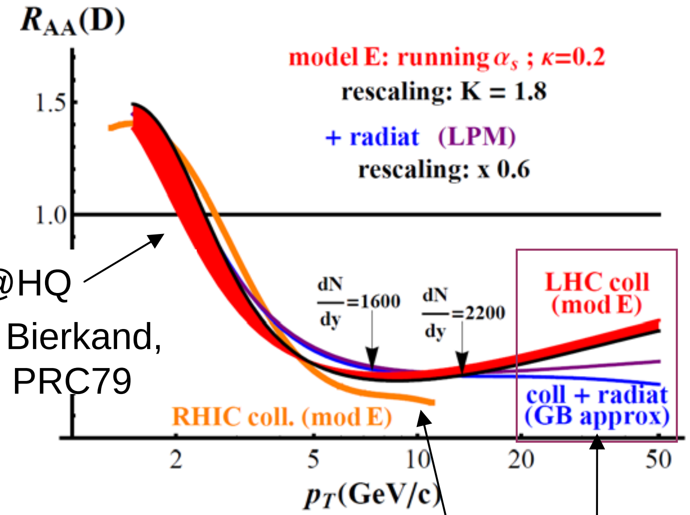
Predictions from several groups for R_{AA} of D mesons in PbPb: (and also some v2)



Armesto , Cacciari, Dainese, Salgado, Wiedemann (last call for LHC):



Wicks, Gyulassy (last call for LHC):



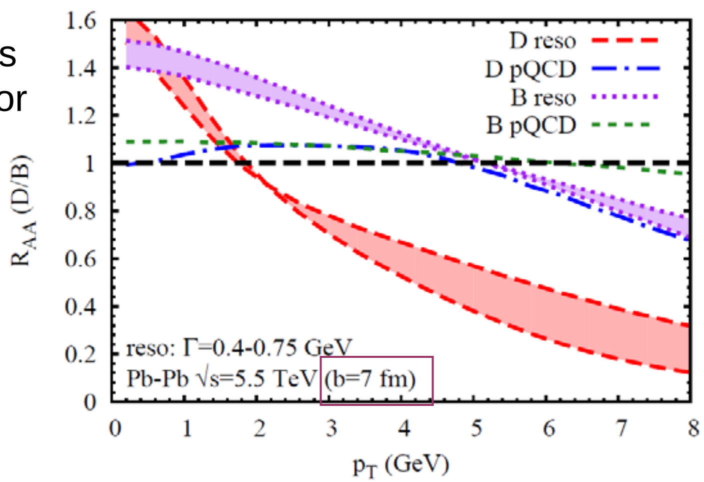
MC@HQ

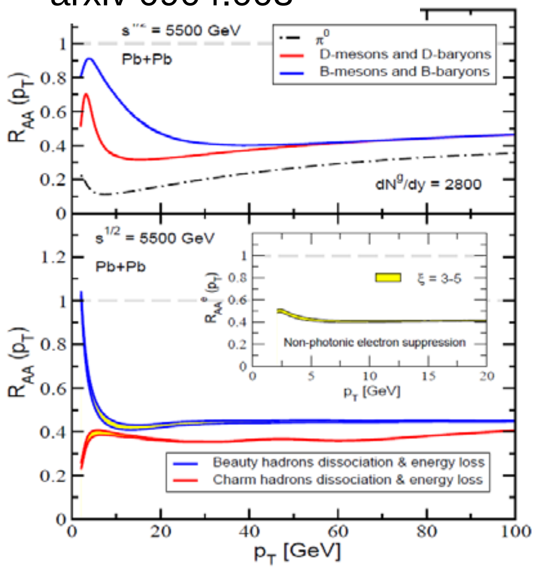
Gossiaux, Bierkand, Aichelin, PRC79

Surprizing transparency ?

Sharma, Vitev & Zhang arxiv 0904.003

Grecco, Van Hees & Rapp (last call for LHC)





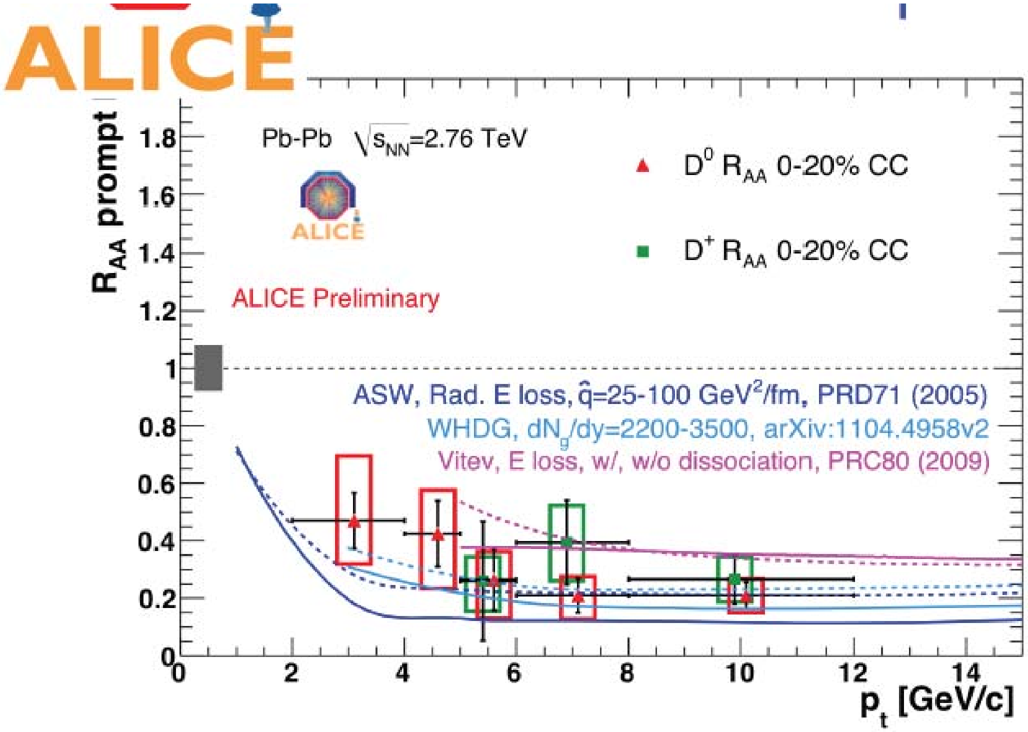
Indeed some hope for model scrutinity

Charming LHC

(prompt) D mesons measured by ALICE

From Dainese, QM 2011

(see Ph. Crochet's Talk)

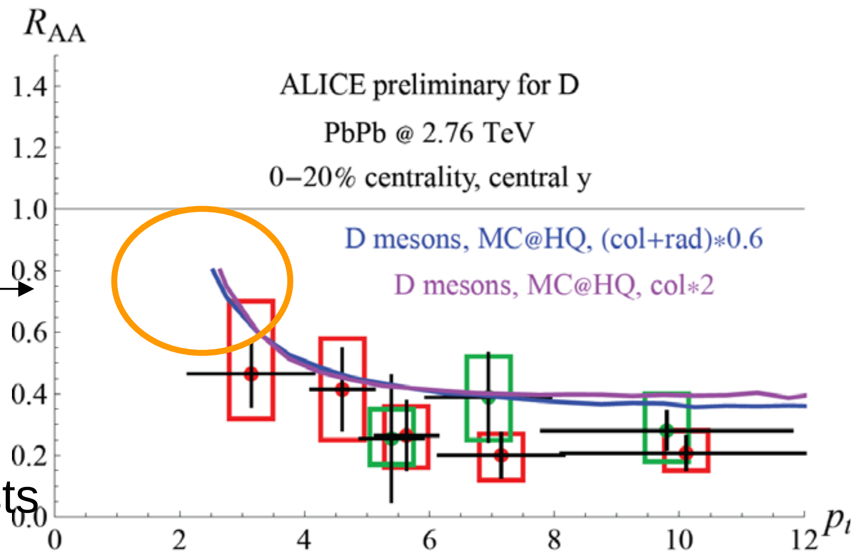


Feeling n°1: Theoretical uncertainty is for the time roughly identical to experimental uncertainty…

R_{AA}(D) alone on this p_t range will not permit to decipher the models easily

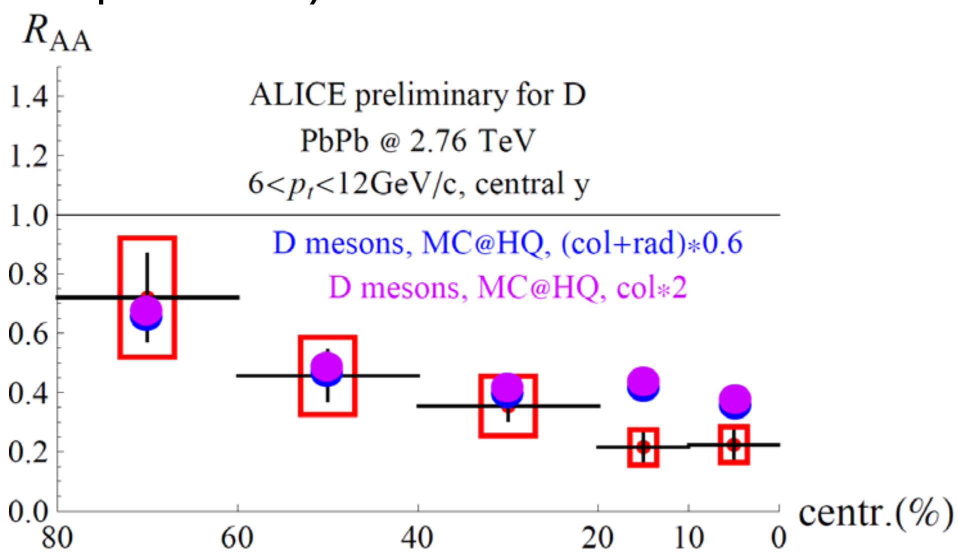
D from ALICE compared with MC@HQ

No Shadowing included in the initial distribution.



Full rescaled collisional still compatible with the data

Vs centrality (important: tests path length dependence)

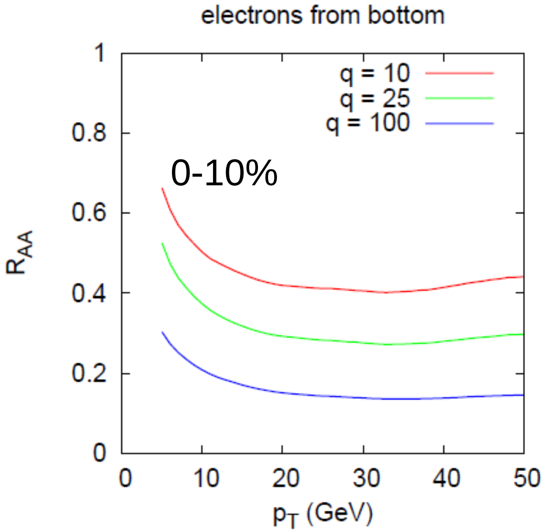


<L>

Centrality dependence rather well reproduced, although some room for L^n behaviour at small L, or some retardation effect…or hydro improvement

Beautiful LHC

Predictions from several groups for R_{AA} of D mesons in PbPb: (and also some v_2)



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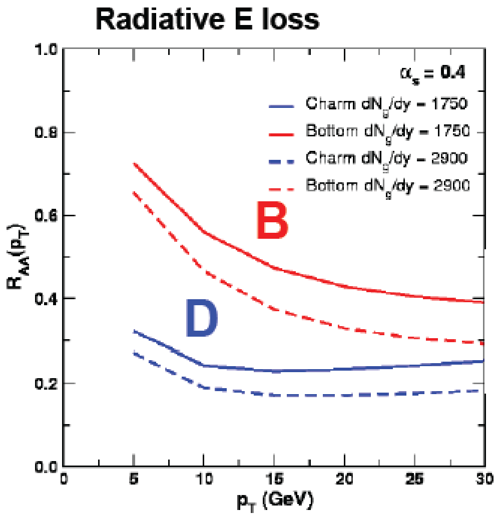

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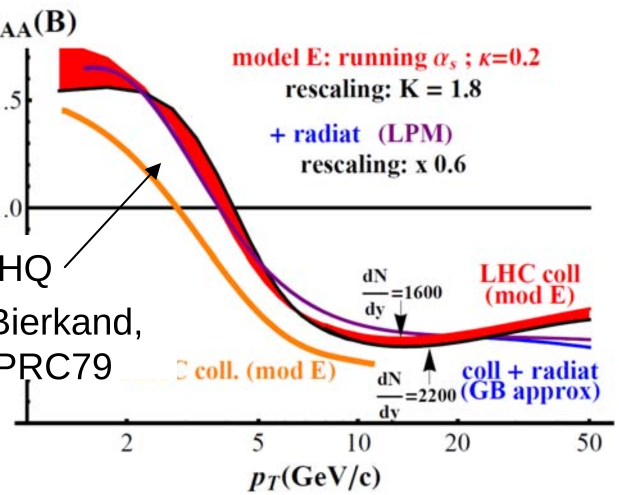

MC@HQ

Gossiaux, Bierkand, Aichelin, PRC79

Sharma, Vitev & Zhang arxiv 0904.003

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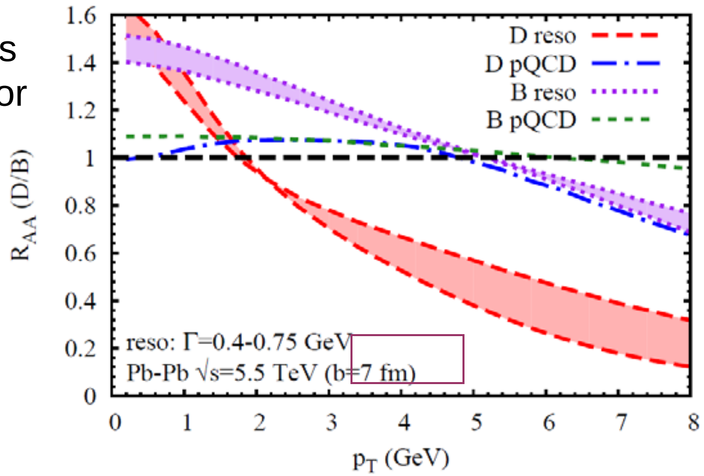
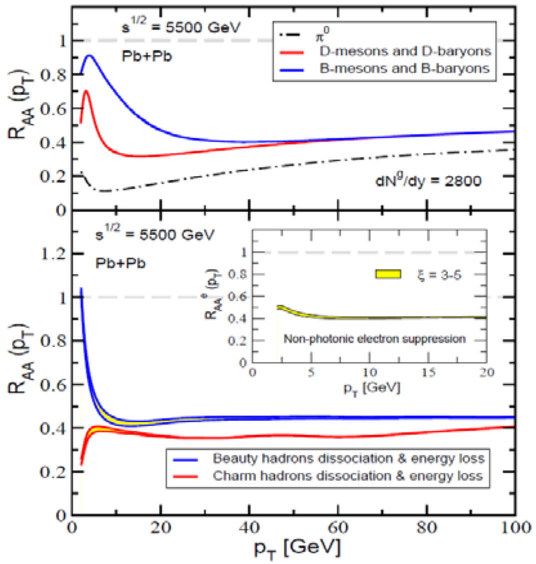
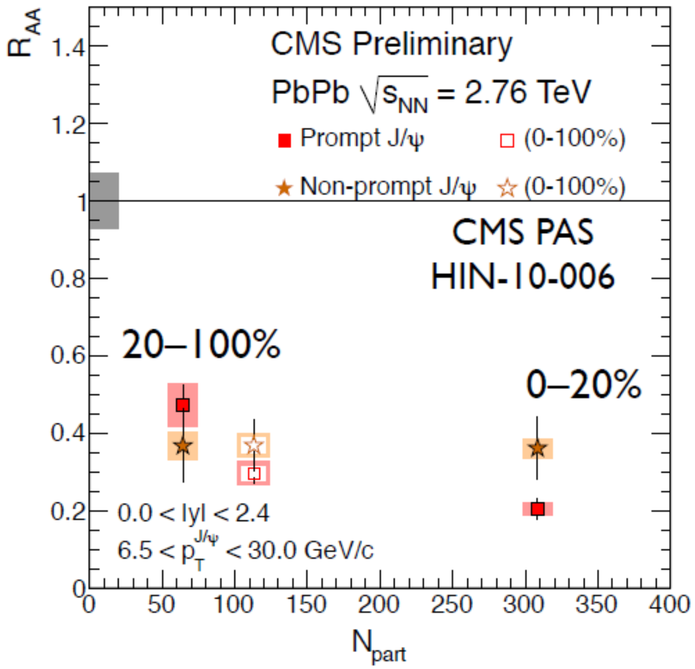


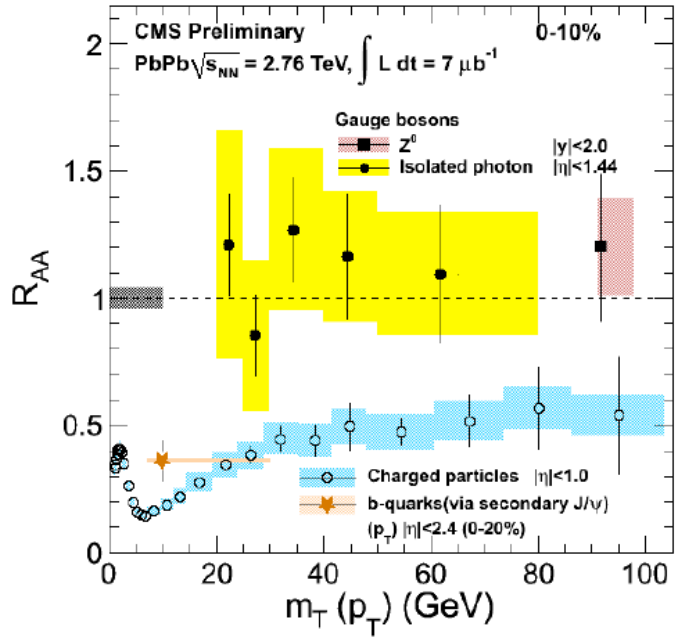


Beautiful LHC

T. Dahms (Bad Honnef 2011)

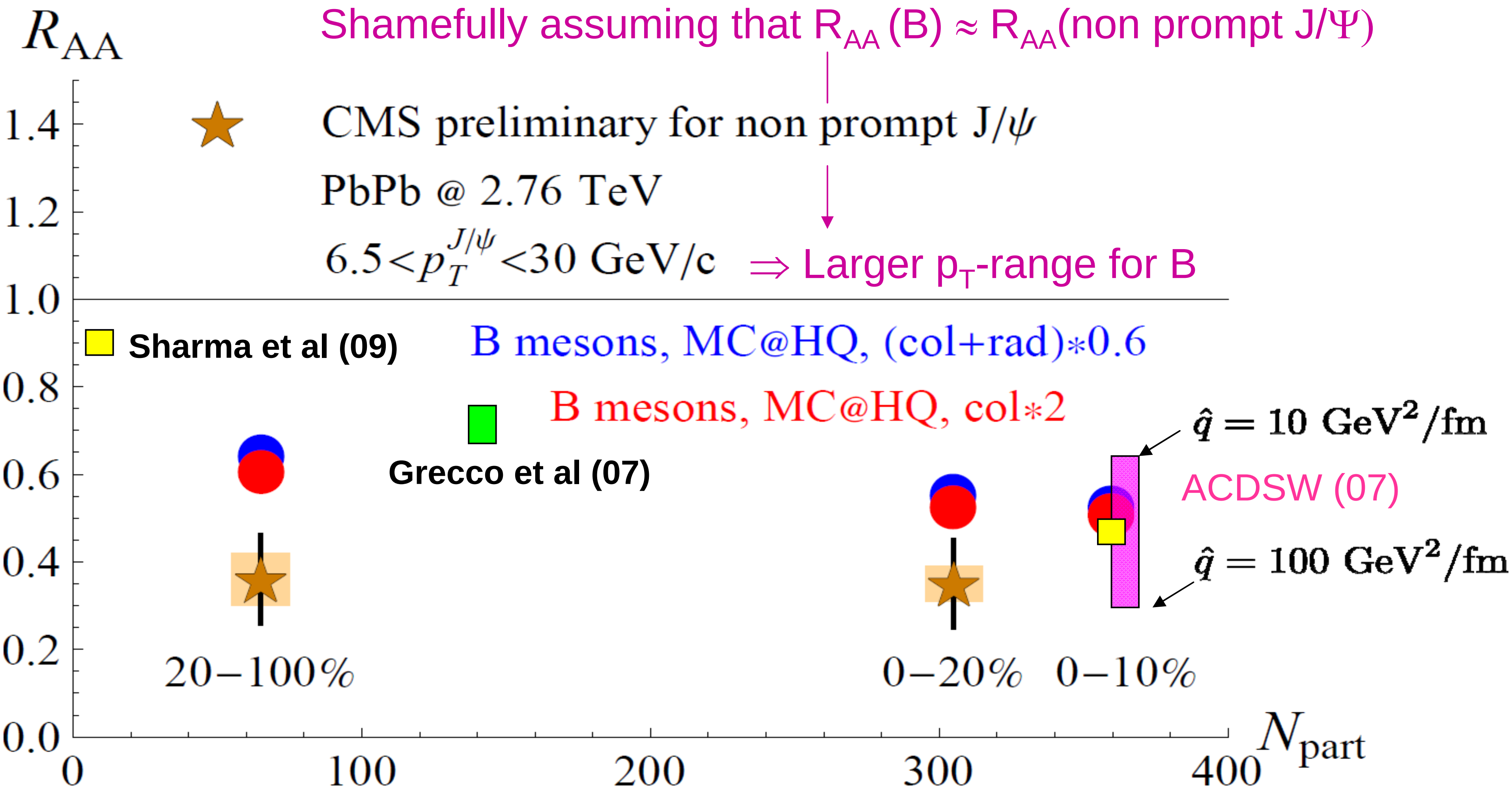
Non-Prompt J/ψ R_{AA}





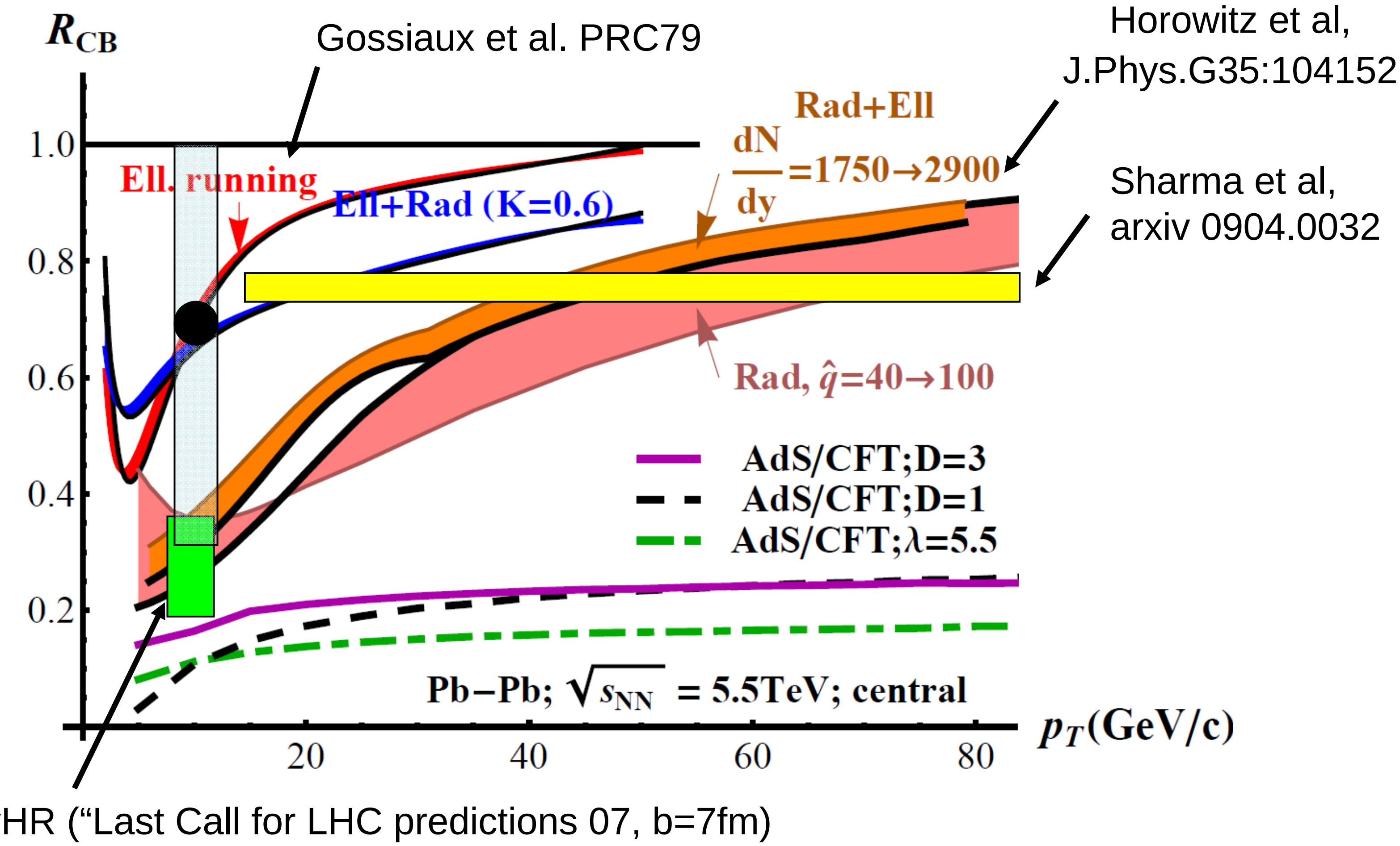
- Suppression of non-prompt J/ψ observed in min. bias and central PbPb collisions
  - First indications of high-p_T b-quark quenching!

B predictions vs CMS data



Most of the models seem to underpredict the B quark energy loss (wait until confirmation and more dedicated work); little centrality dependence in the data (still compatible with L dep.).

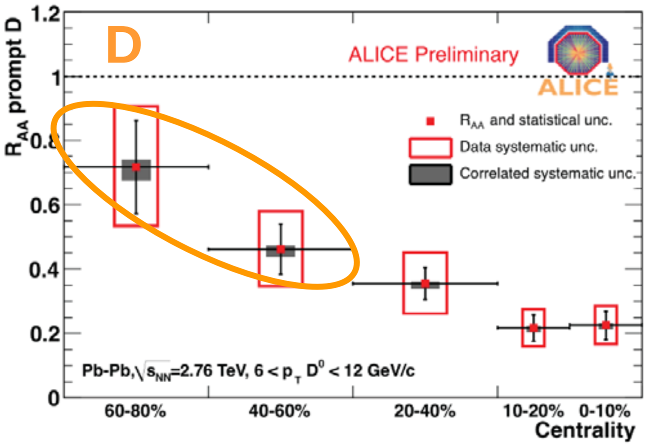
Resolving mass dependences @ LHC

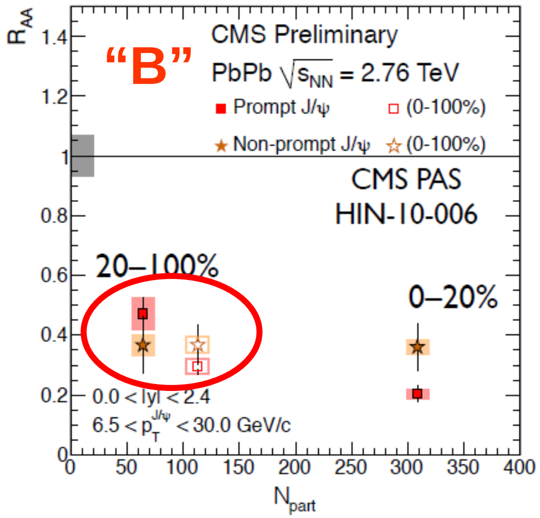


Feeling n°2: Comparison between preliminary data and models seems to disfavor models based on AdS/CFT

Muons @ LHC

Checksum for c & b… and some intriguing feature looking at preliminary data for large centralities:



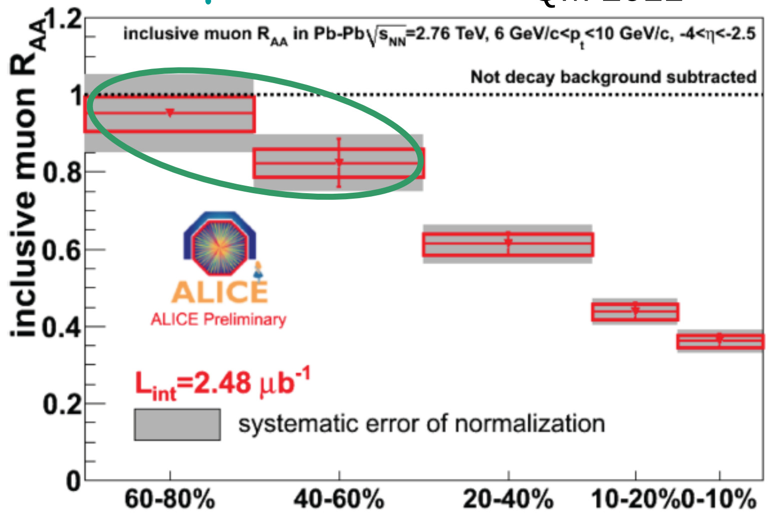


"+"

How can we have $R_{AA}(\mu)$ close to 1 if b source if so quenched in non-central events ?

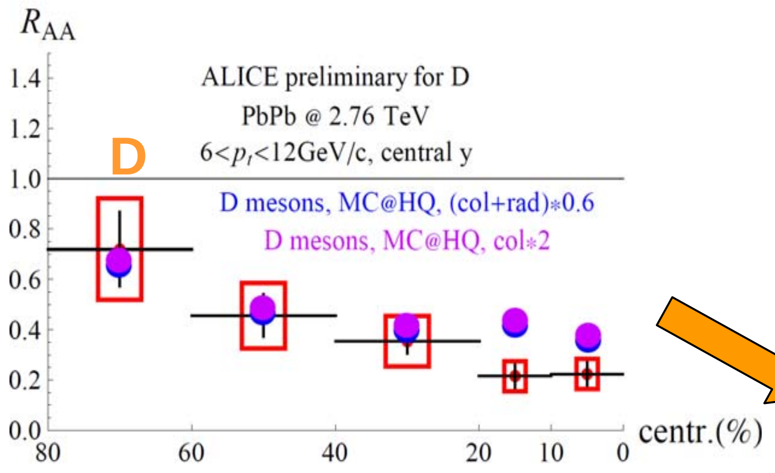
From Dainese, QM 2011

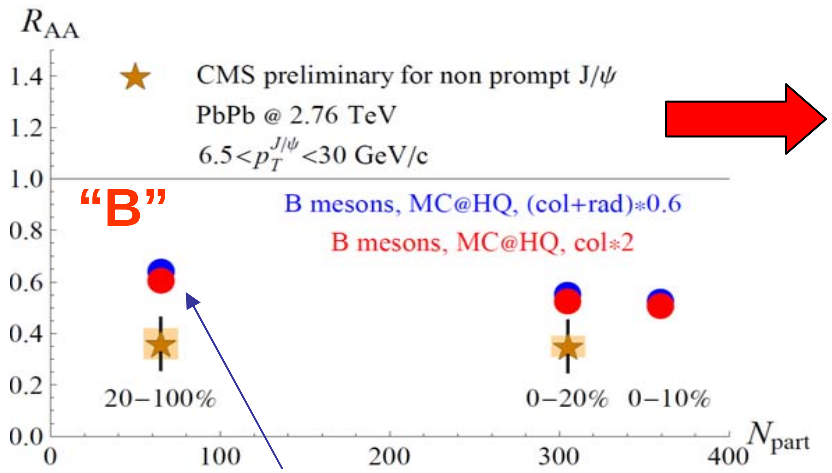
μ



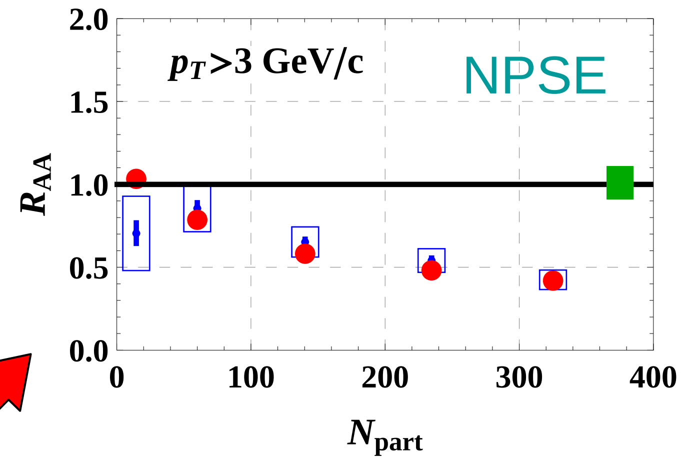
Now, one can wonder about centrality classes as well as p_t and |y| ranges => use MC@HQ as a unifying tool

Muon analysis based on MC@HQ

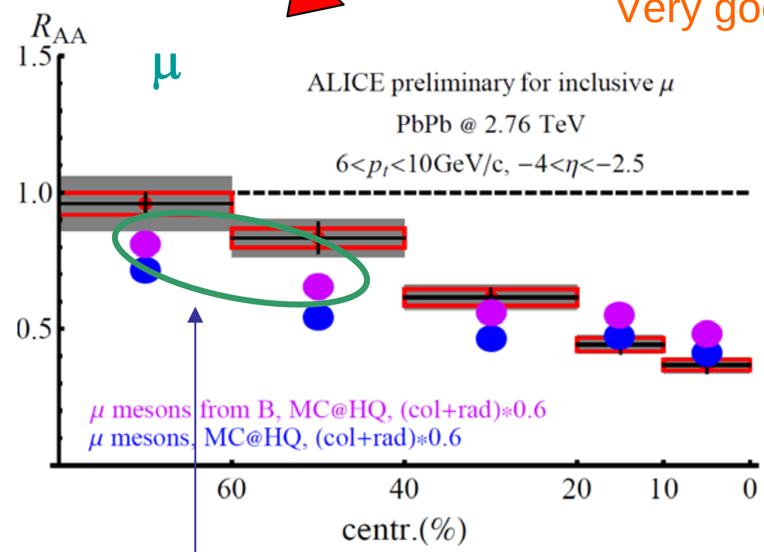




Too high



Very good agreement at RHIC



In conflict with

Too low, even for μ←B

However, remember: "Shamefully assuming that R_{AA} (B) ≈ R_{AA}(non prompt J/Ψ)"

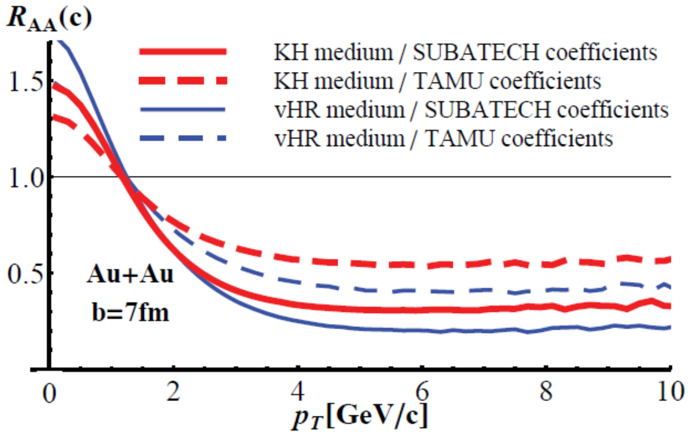
Wait for genuine B measurement

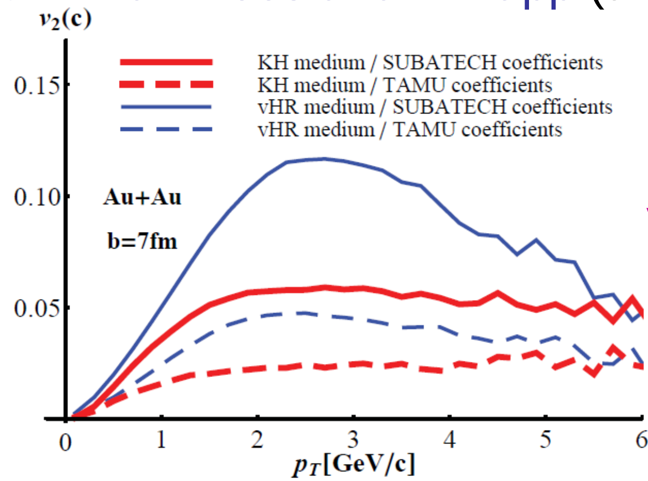
Improvements needed from the theory side

Key issue: systematic consideration of the dynamical “underlying event” (e.g. the hot medium) on the Energy loss of heavy quarks (see “global fit” approach in Steffen Bass’s talk)

Exemplification:

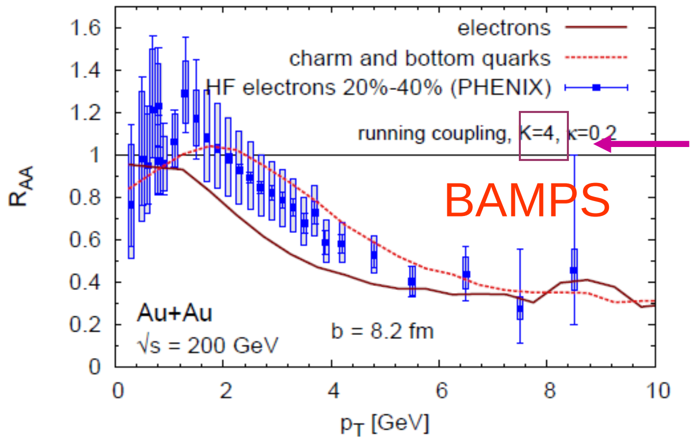
a) Systematic analysis performed with H van Hees and R Rapp (arxiv 1102.1114)



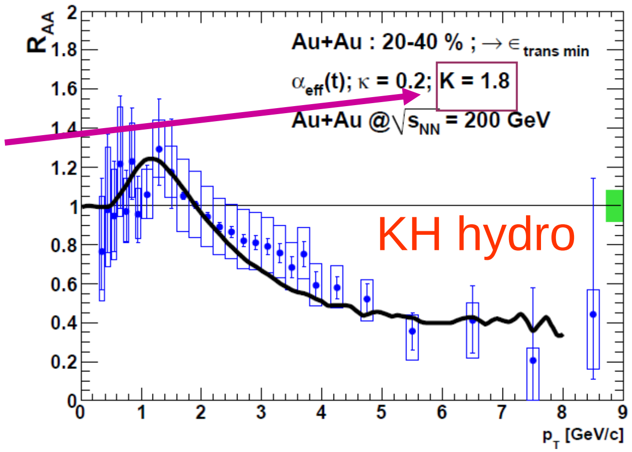


Larger thermalisation in vHR medium than in Kolb-Heinz hydro

b) Running α_s approach in BAMPS (Uphoff et al. arxiv 1104.2437)



Apparently, 2 times less thermalisation in BAMPS then in Kolb-Heinz hydro



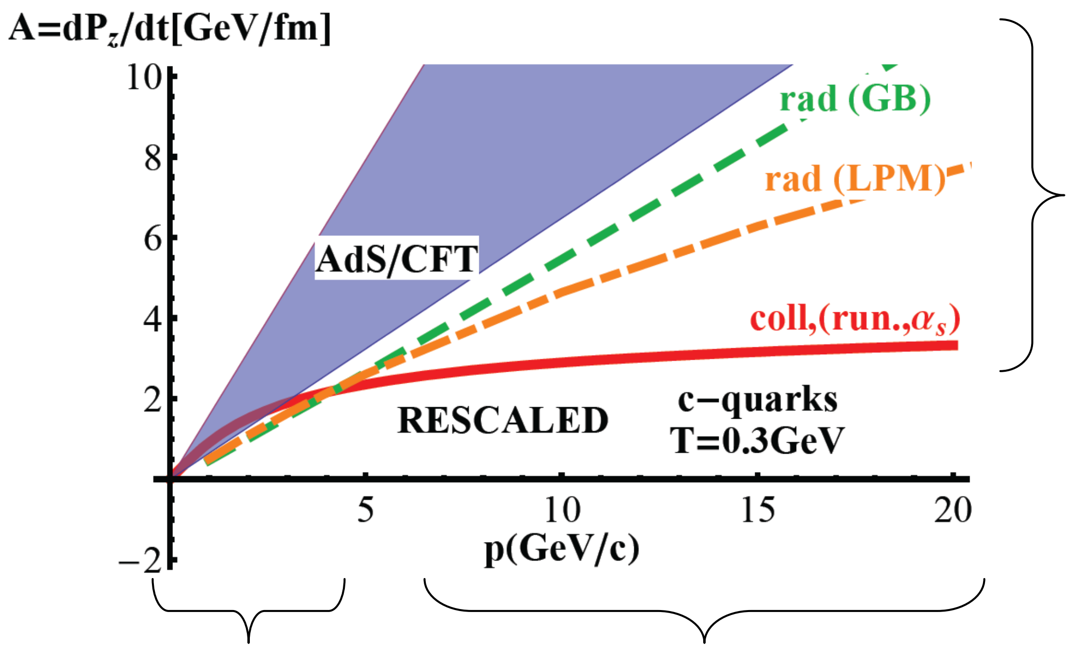
Conclusions

Shared among HQ community → [color gradient bar] ← In conflict with other's scientist lessons

- Several models containing either non pertub. features or tunable parameter able to reproduce the HQ data, but many questions remain… and how to reconcile them all stays a challenge
- No deviation from linear path length dependence mandatory from RHIC HQ data (that I know of)
- RAA observable is mostly sensitive to the probability of energy loss at low values, what makes difficult to decipher between models
- It is nevertheless possible to extract some fundamental properties of the QGP (such as the diffusion coefficient), with successful comparison to the lattice calculations
- Early LHC results are in gross agreement with predictions (dislike at the RHIC time), and seem to favor models based on pQCD or pQCD + non perturbative ingredients.
- Disentangling between various models remains at the time a challenge and requires a) more precision from the experiments as well as b) global approaches (but beware of shallow mimimums)
- R_{cb} is probably the best deciphering observable in the near future

Conclusions

Global view



Drag coeffient evaluated in several theories all compatible with RHIC observables

“fixed” by RHIC Not “fixed” by RHIC, might not be fixed by LHC

Full lattice calculation of (at least) drag coefficient at γ=5-10 is mandatory in order to rule out some theories