Progress in the MC simulation of jets and jet quenching

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5th JET collaboration meeting, UC Davis, June 17-18, 2013

Outline

1) Outline of project plan

2) Concise description of completed projects

3) Detailed description of projects completed in 2013-14

4) Emergent issues and their solution.

5) Description of remaining projects

6) Timeline for completion.

Grand scheme

- Initial state MC Glauber model for nucleons
- Production of hard jets, correlated with charged particle production
- Space-time dependent shower modification
- Hadronization of jets in vacuum
- Incorporate jets in fluid dynamics
- Hadronization of jets and medium

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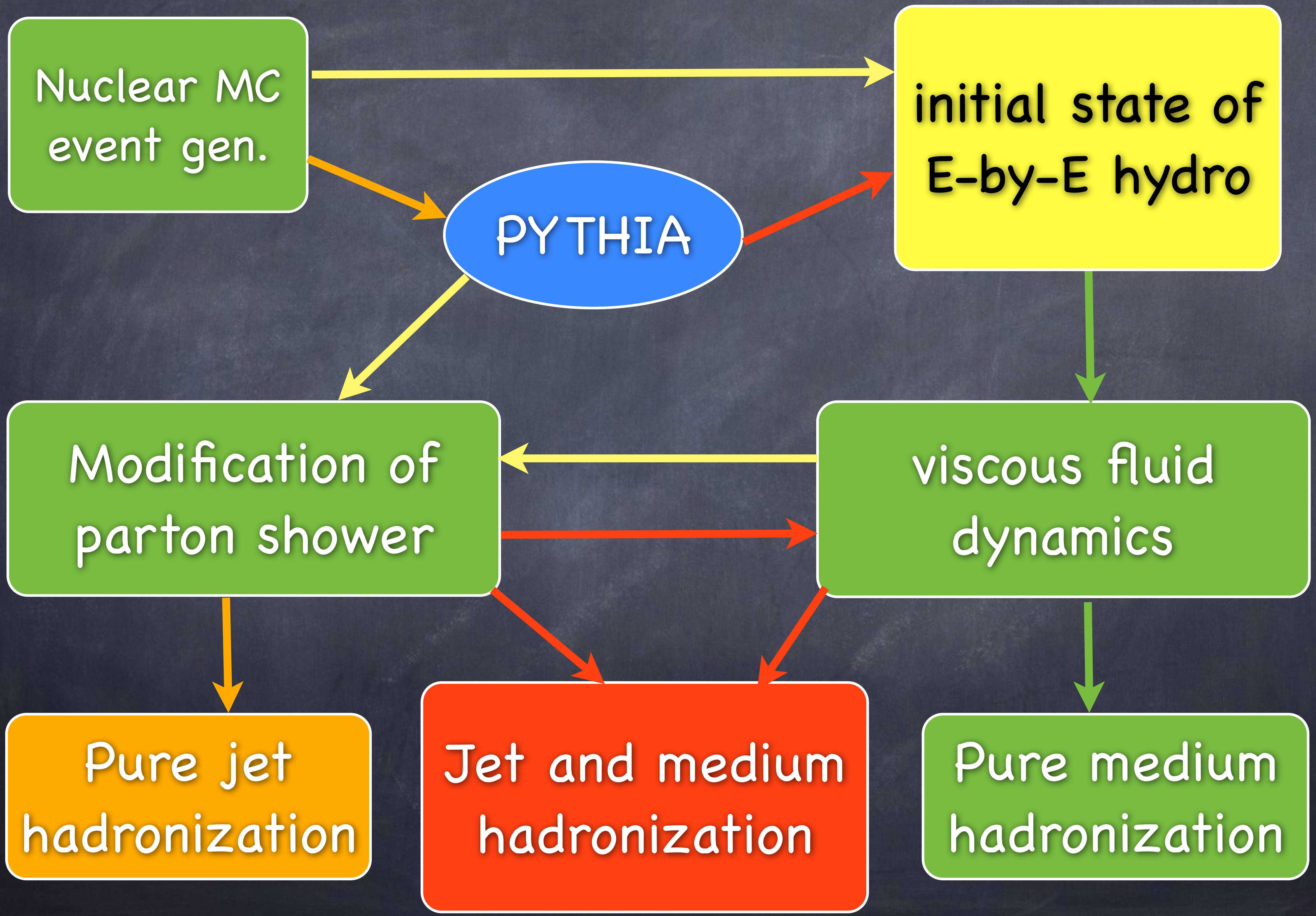
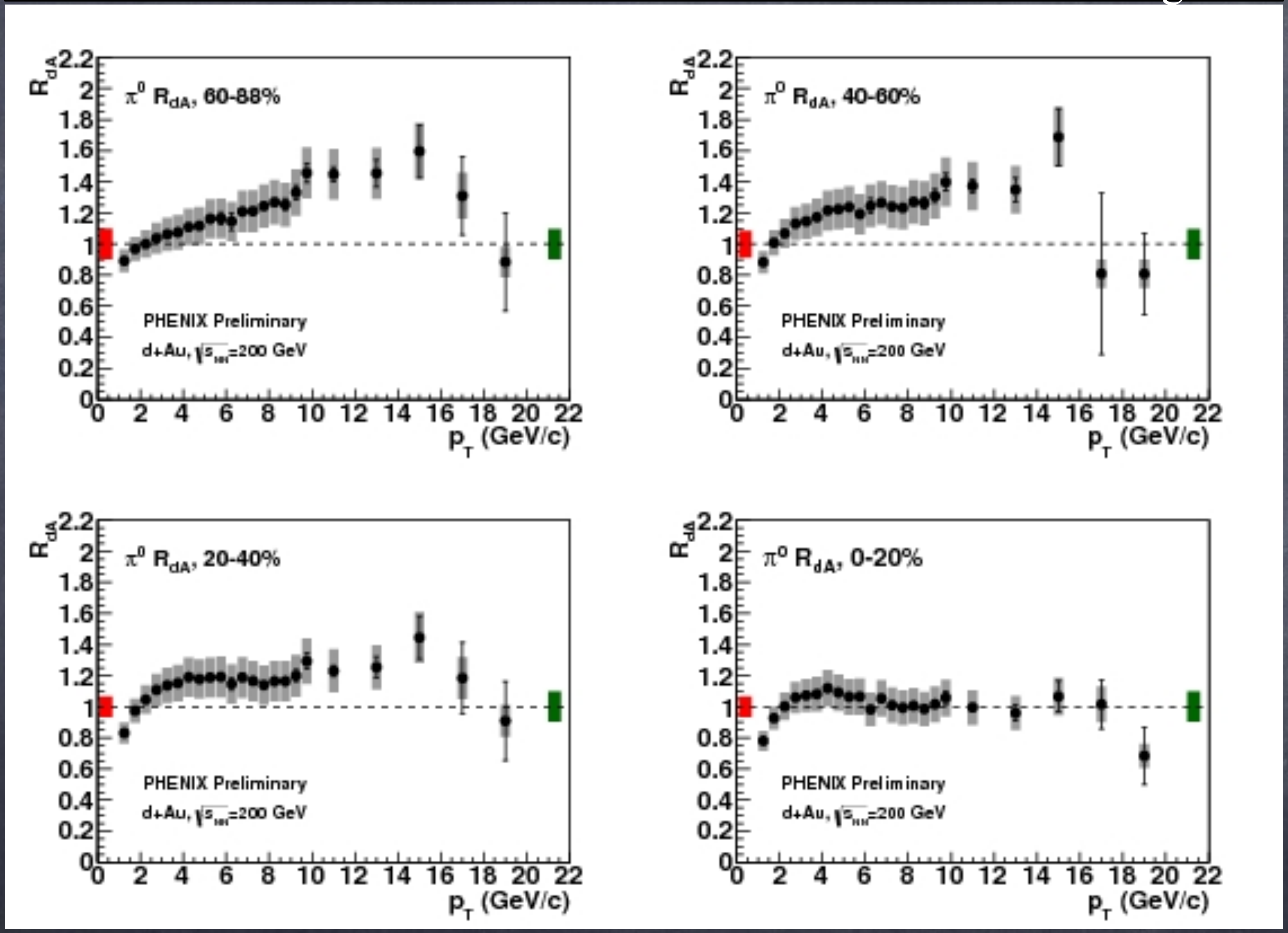
Basic Scheme



Initial state issues

p-Pb, d-Au are baseline measurements which must be described by our MC setup.

R_{dAu} PHENIX in Centrality bins by N_{chg}



Odd enhancement of R_{dAu} in peripheral, small suppression in central event

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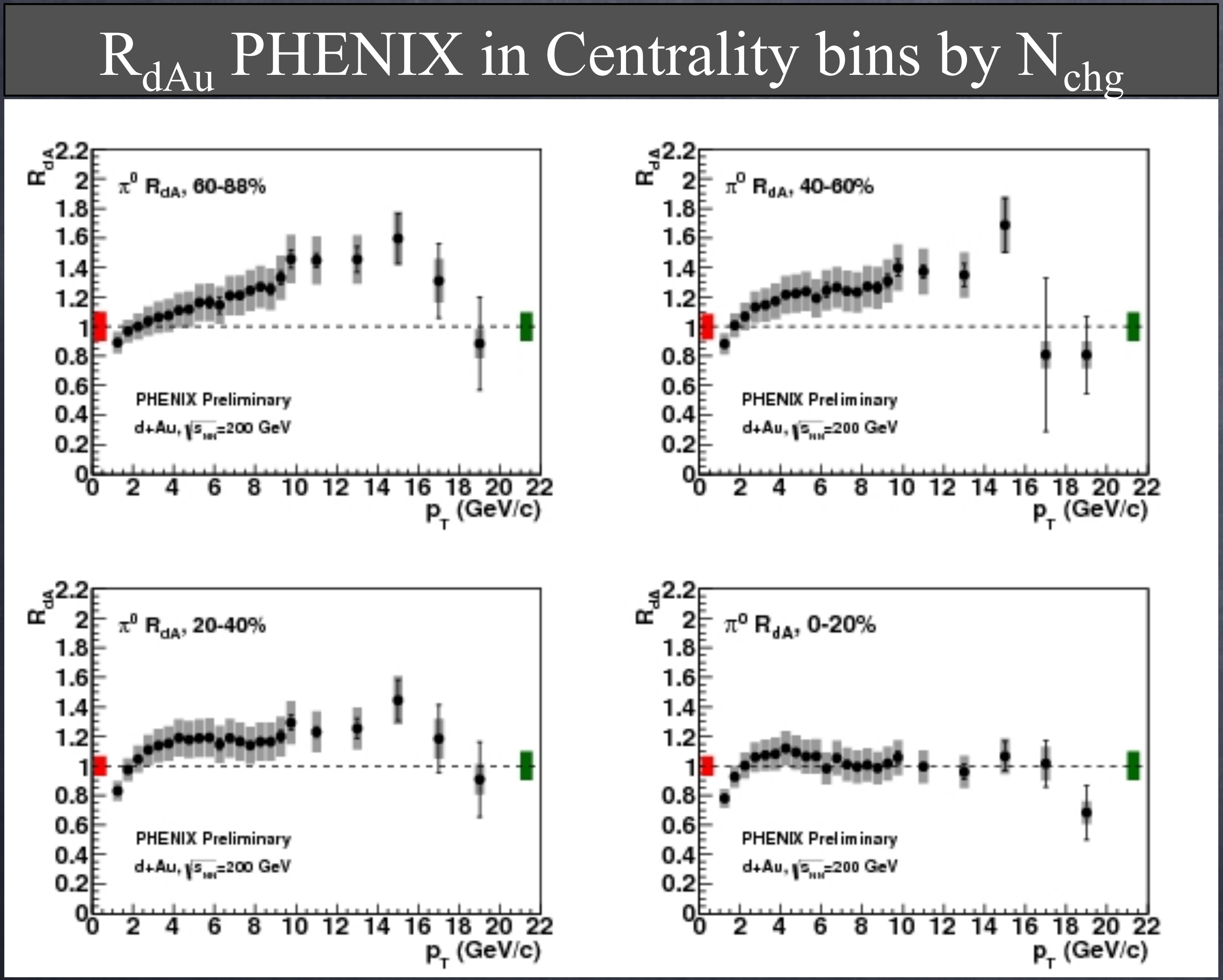

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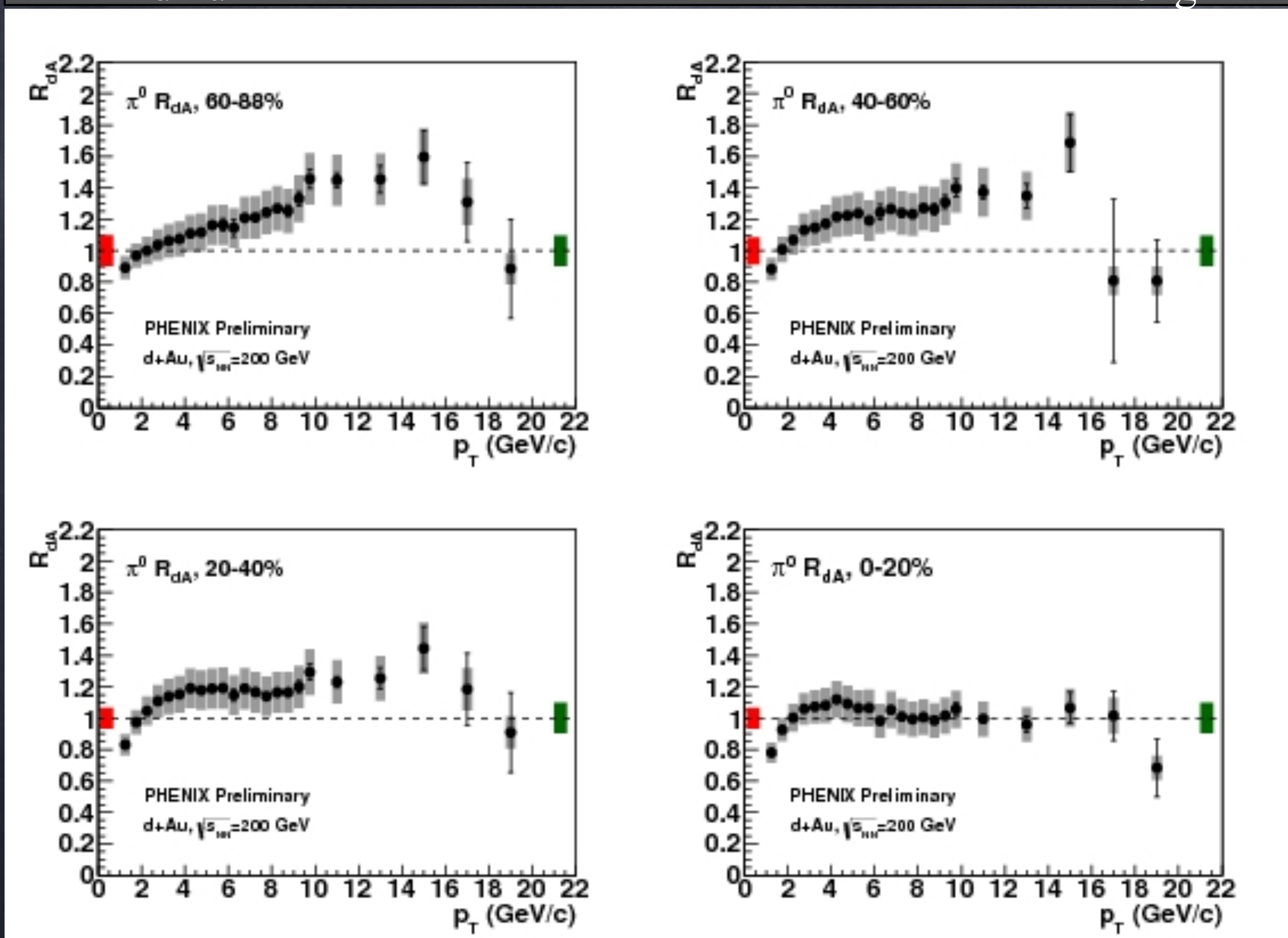
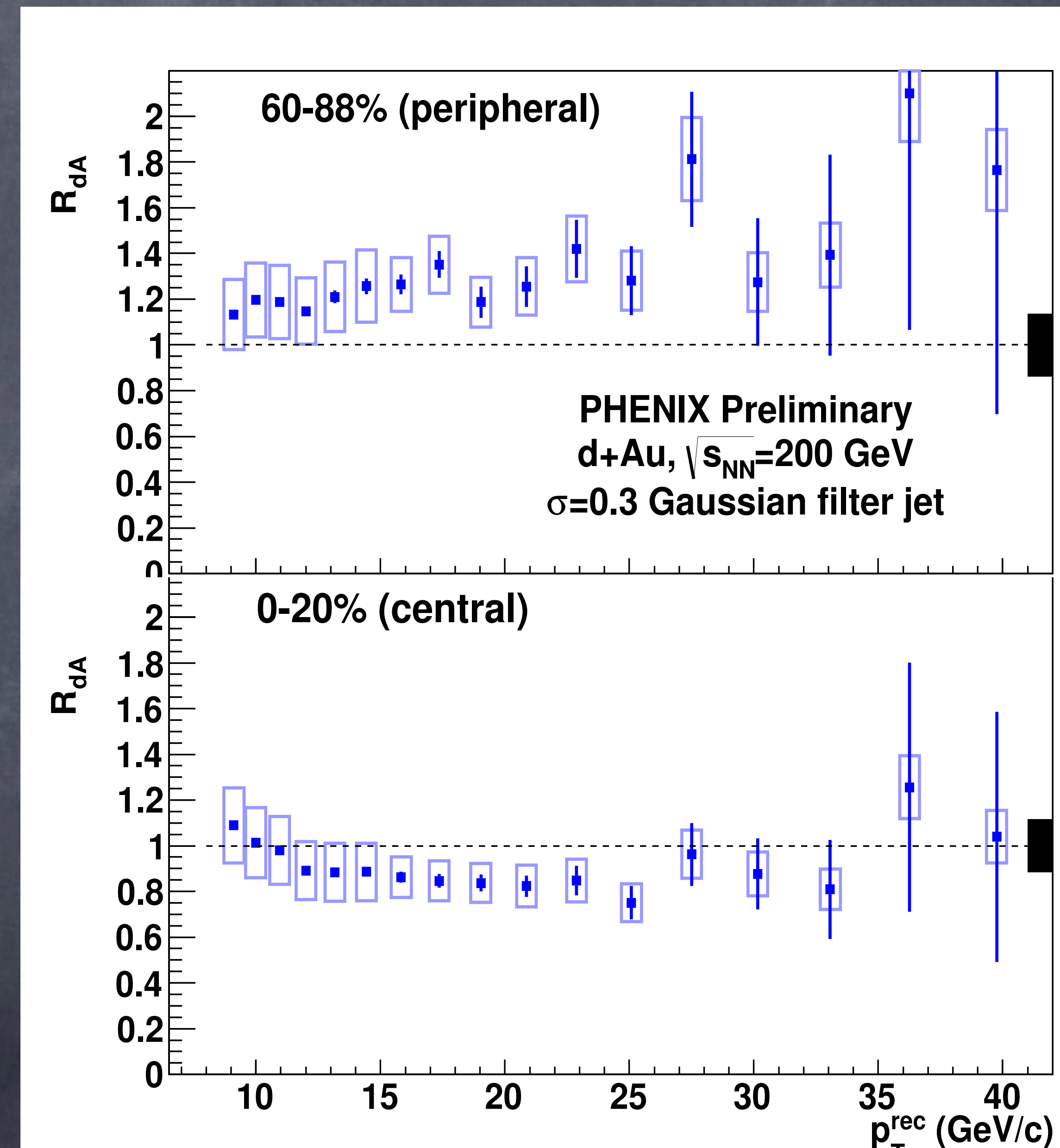




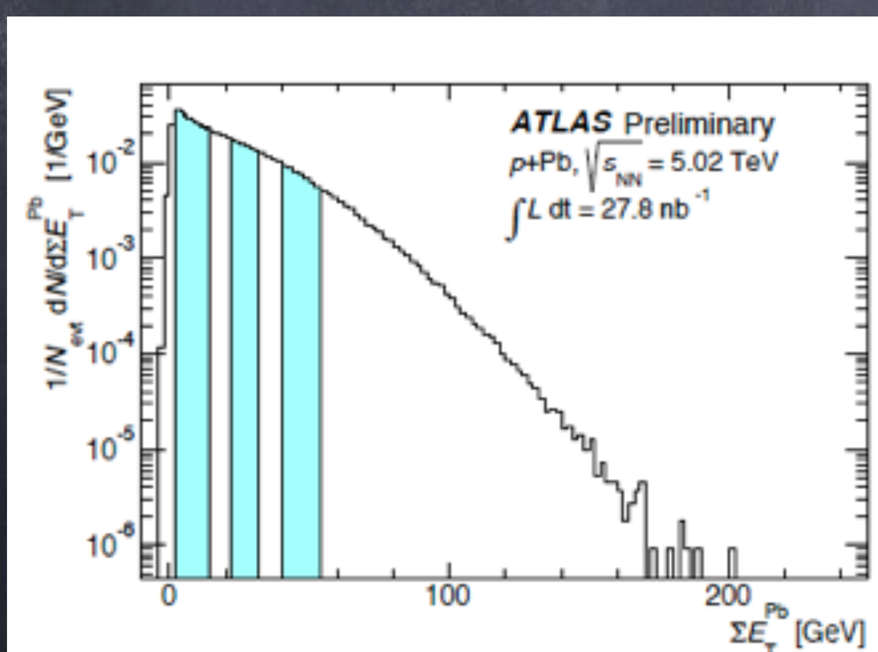
Odd enhancement of R_{dAu} in peripheral, small suppression in central event

Same pattern seen in LHC p-Pb

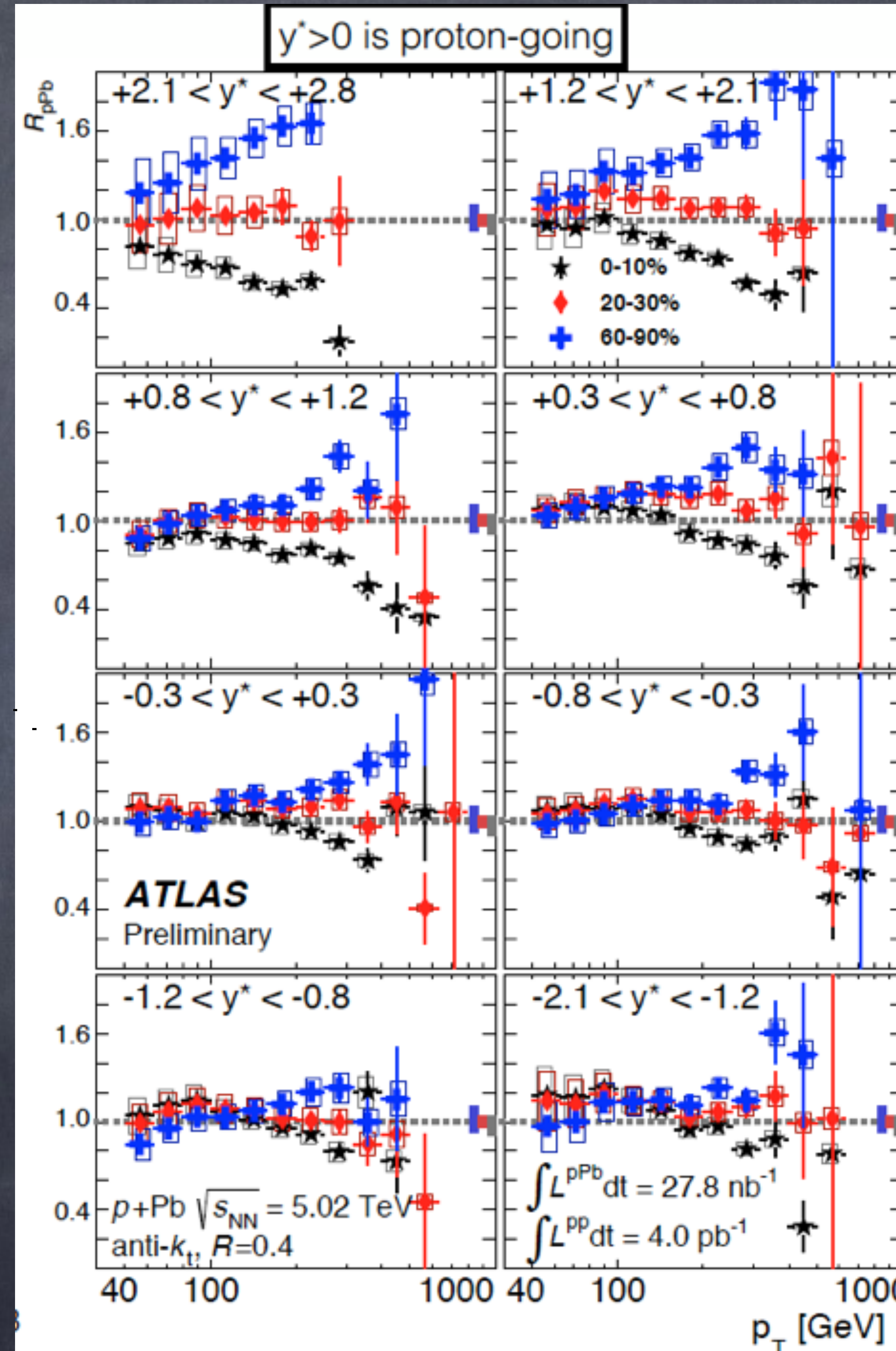
Stronger effect at LHC energies

Effect increases in p direction and less in Pb direction

Effect increases with jet p_T

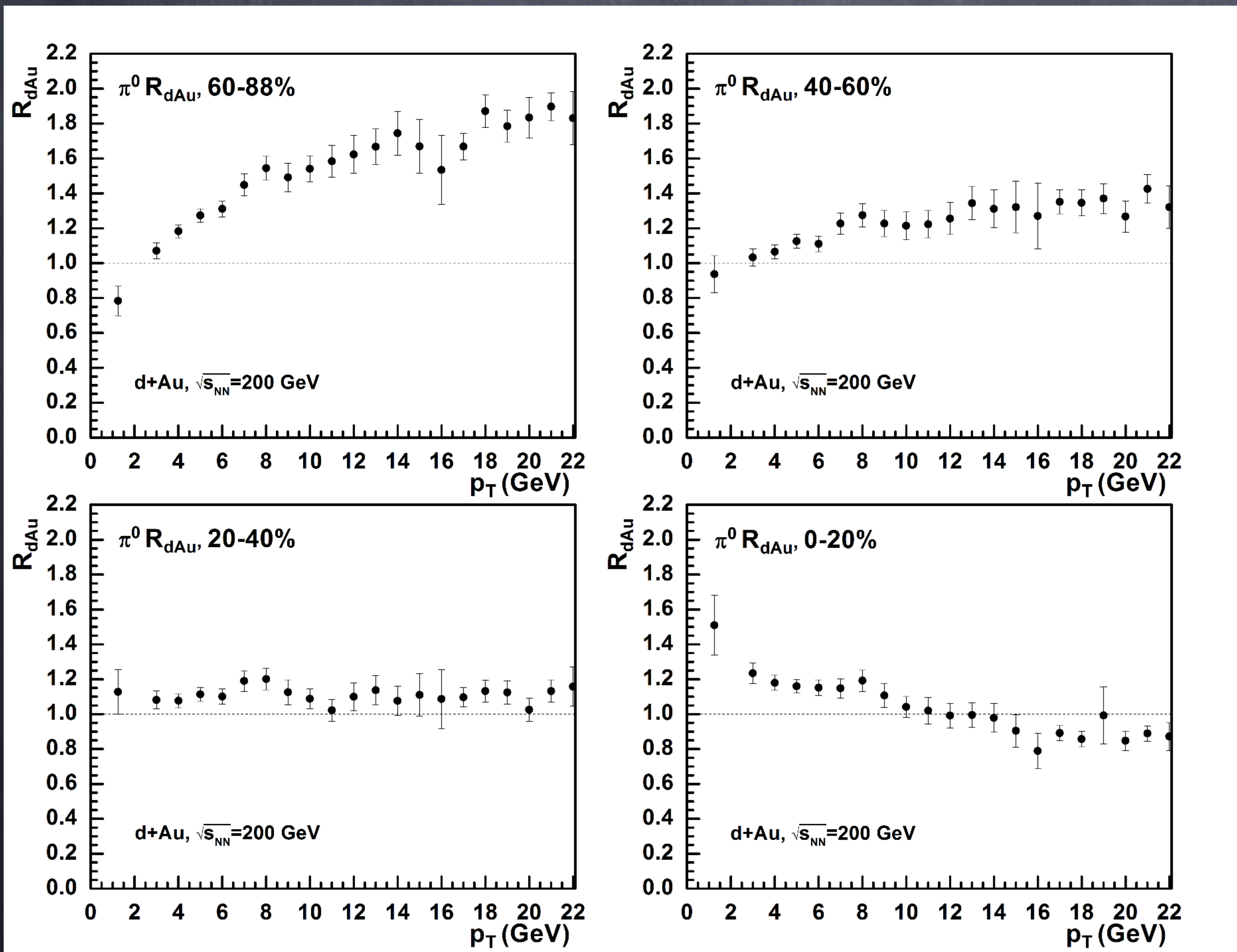


Centrality determined using ΣE_T in Pb-going FCal, $-4.9 < \eta < -3.2$, default Glauber

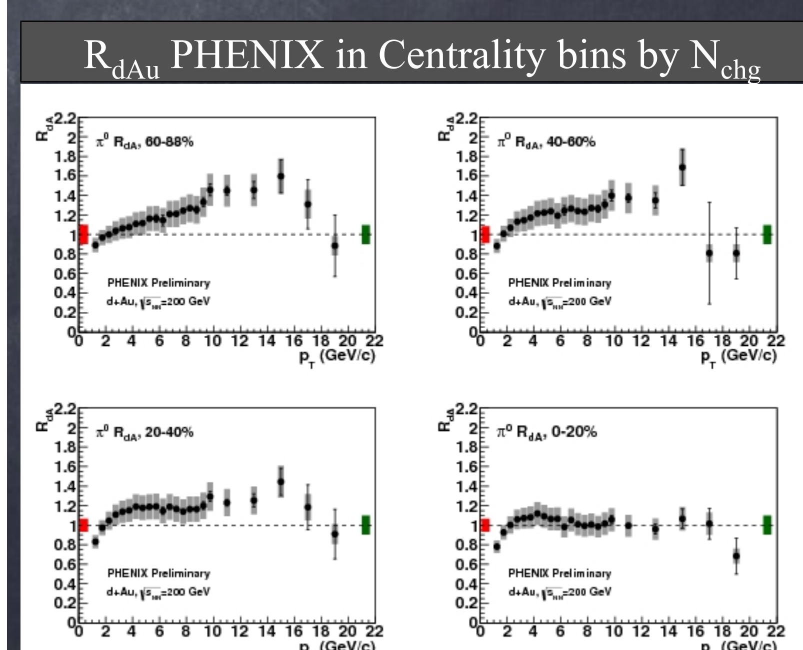


Preliminary results from MATTER++ can explain this effect

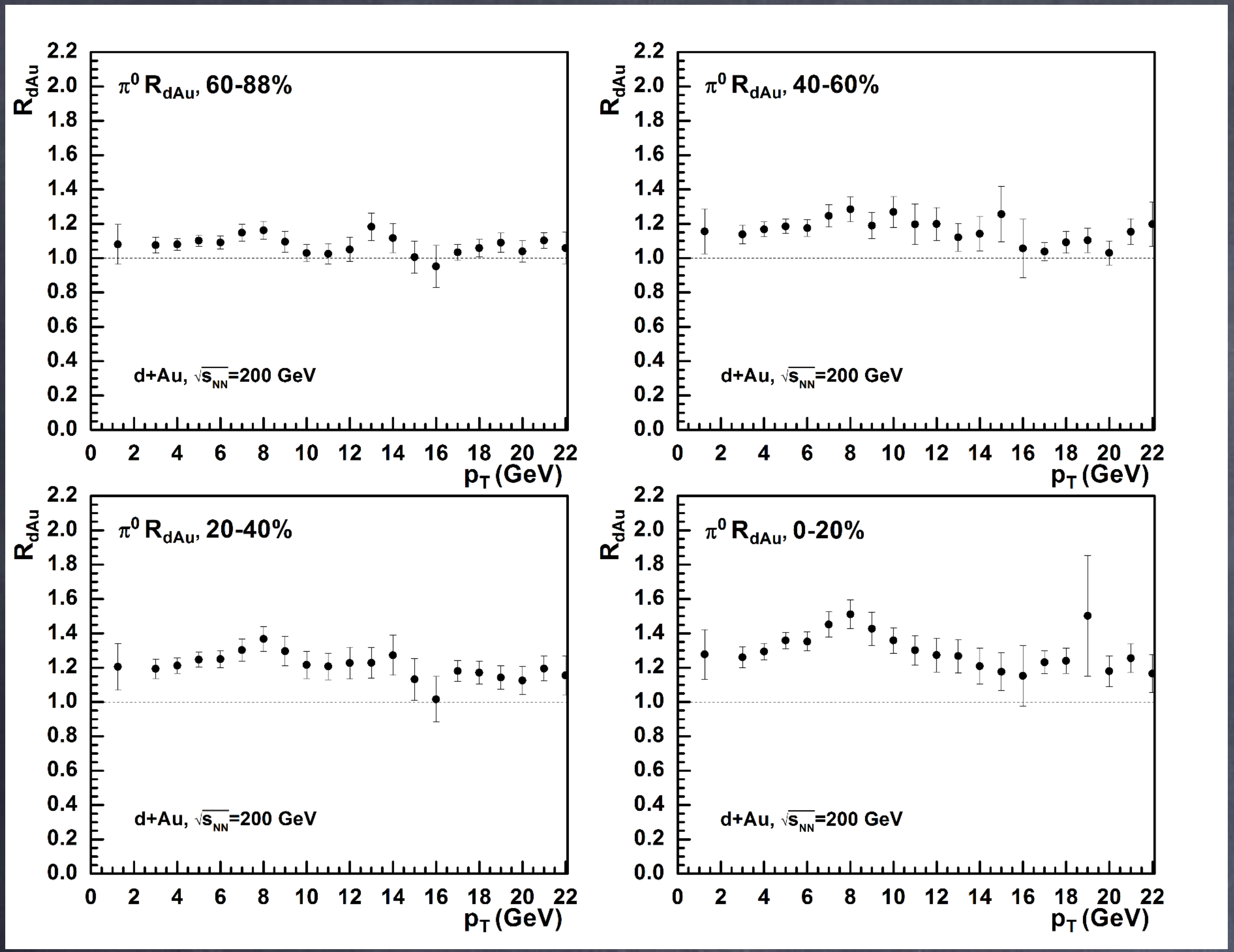
To appear: M. Kordell and AM 2014

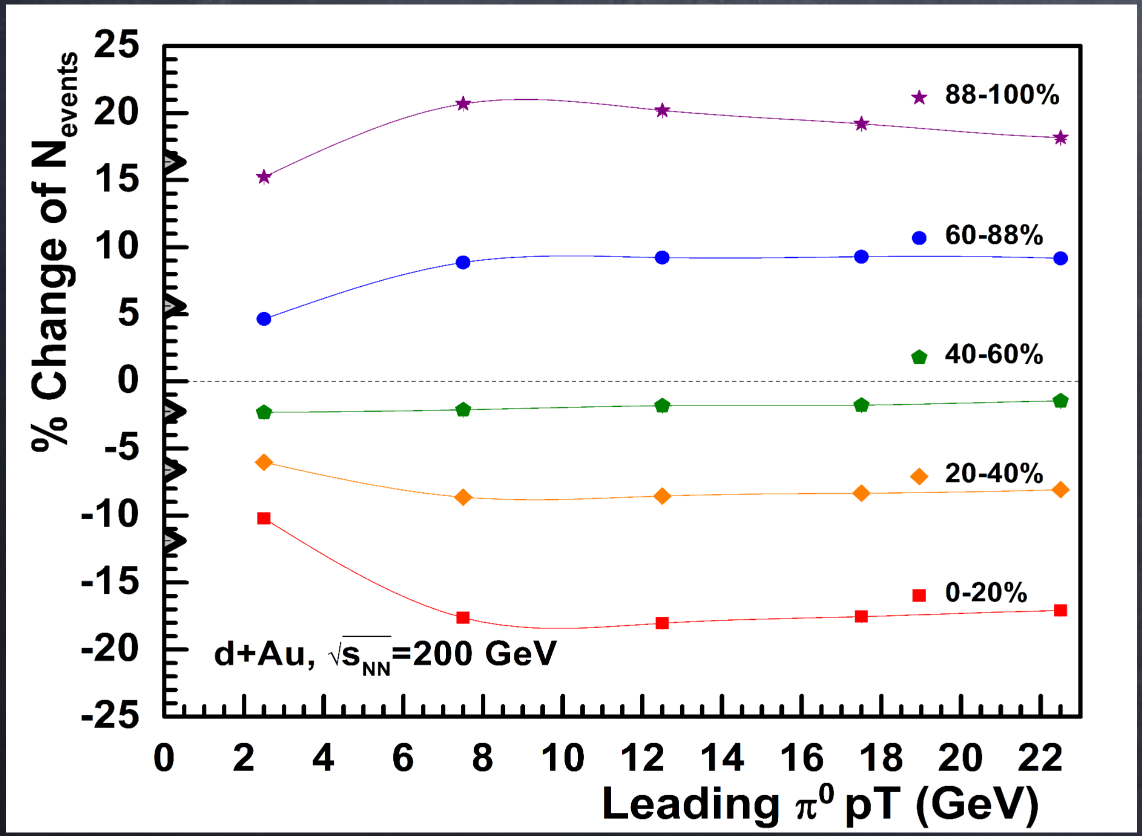


Results of binning in N_{ch}
Similar to Expt.



The Reason





Proton remains frozen in few parton high-x state during collision.

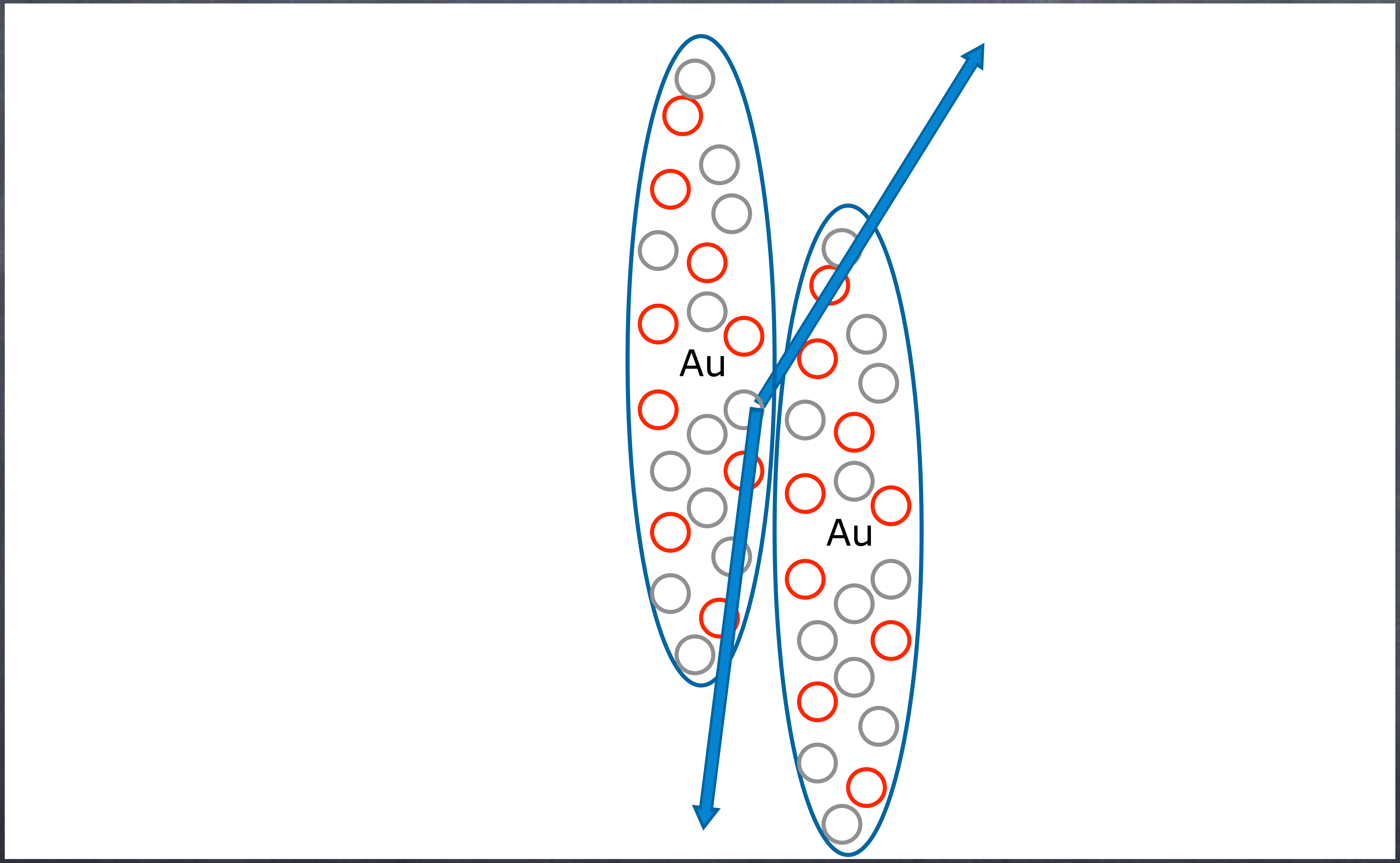
Fewer soft partons means less particle production and thus events are labeled as peripheral events

No effect, if events by N_{coll}

Can compute the shift between N_{coll} and N_{ch} binning

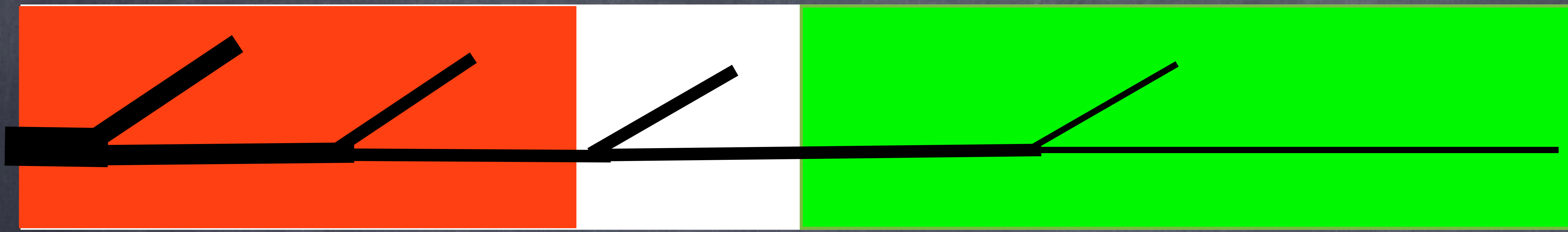
Two methods for hydro and jet e-loss start

We could parametrize the initial state based on the N_{part} or N_{coll} profile in each event. Straight from nuclear MC.



We can parameterize based on the N_{chg} profile in each event based on running PYTHIA. This will be different event to event.

Two (+?) regimes of jet quenching



$Q^2 >> \hat{q}L$

$Q^2 \sim \hat{q}L$

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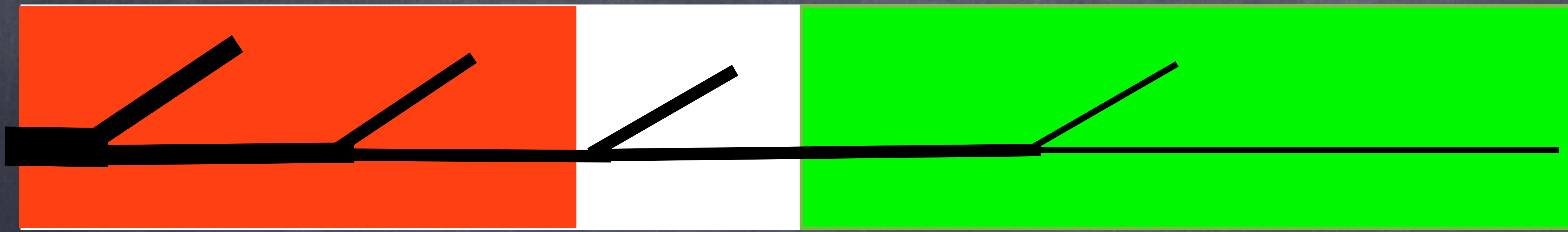

$Q^2 >> \hat{q}L$

Q rises and falls, over all there is a drop!

DGLAP regime, $\alpha_S(Q >>> \Lambda_{QCD})$

Angular/l_T ordering of emissions

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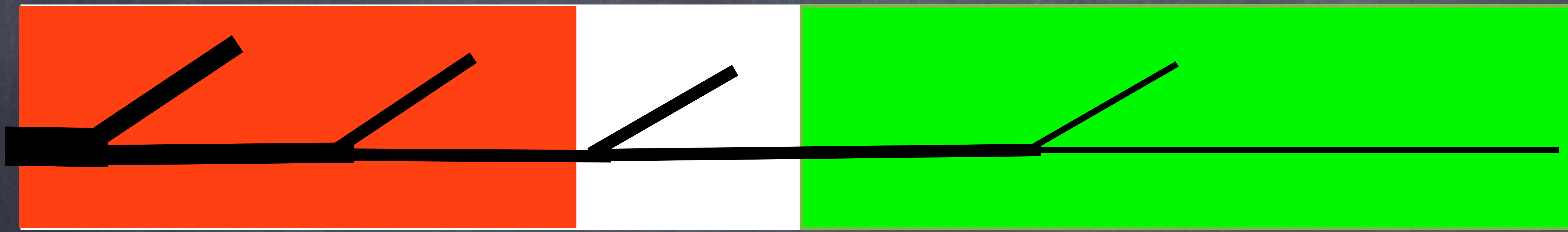

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AMY(BDMPS) regime,
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Radiation α_S suppressed
widely separated emissions

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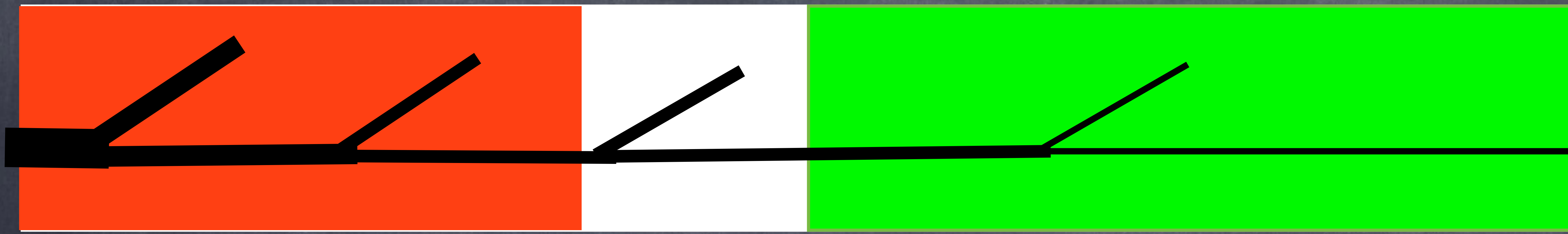

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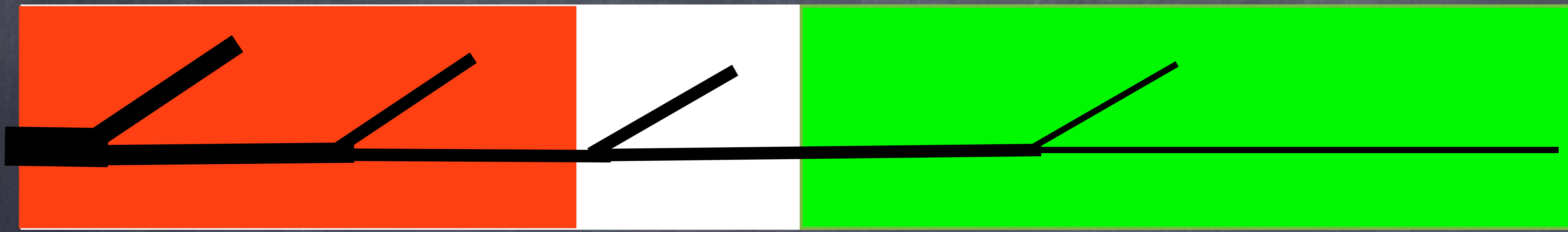

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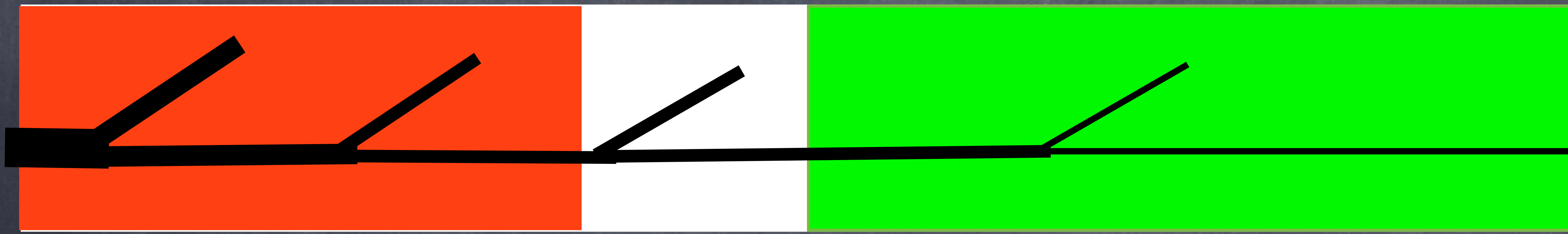

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MATTER++ a HT based MC event generator

Re-introduction of space-time

In light-cone components, the wavefunction is

$$\psi(q) e^{iq^- y^+} e^{iq^+ y^-} e^{-iq_\perp y_\perp}$$

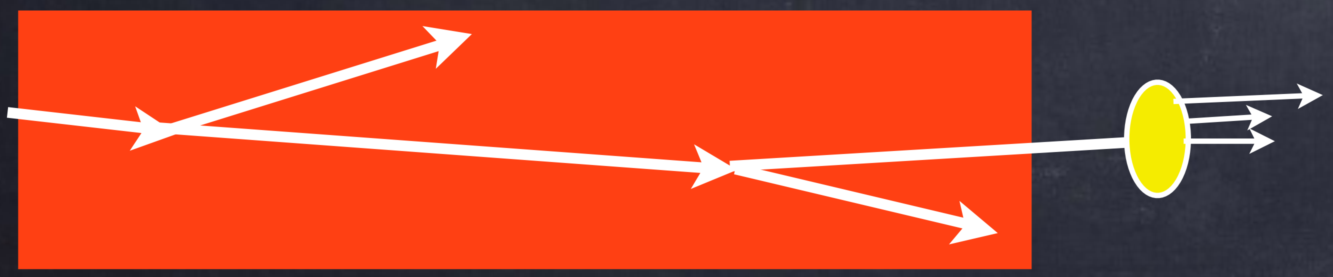
one needs to keep track of y^-

in probability of parton, phase from amplitude and c.c.

$$[e^{iq^- y^+} e^{iq^+ y^-} e^{-iq_\perp y_\perp}][e^{-iq'^- y'^+} e^{-iq'^+ y'^-} e^{ik'_\perp y'_\perp}]$$

focussing only on q^+

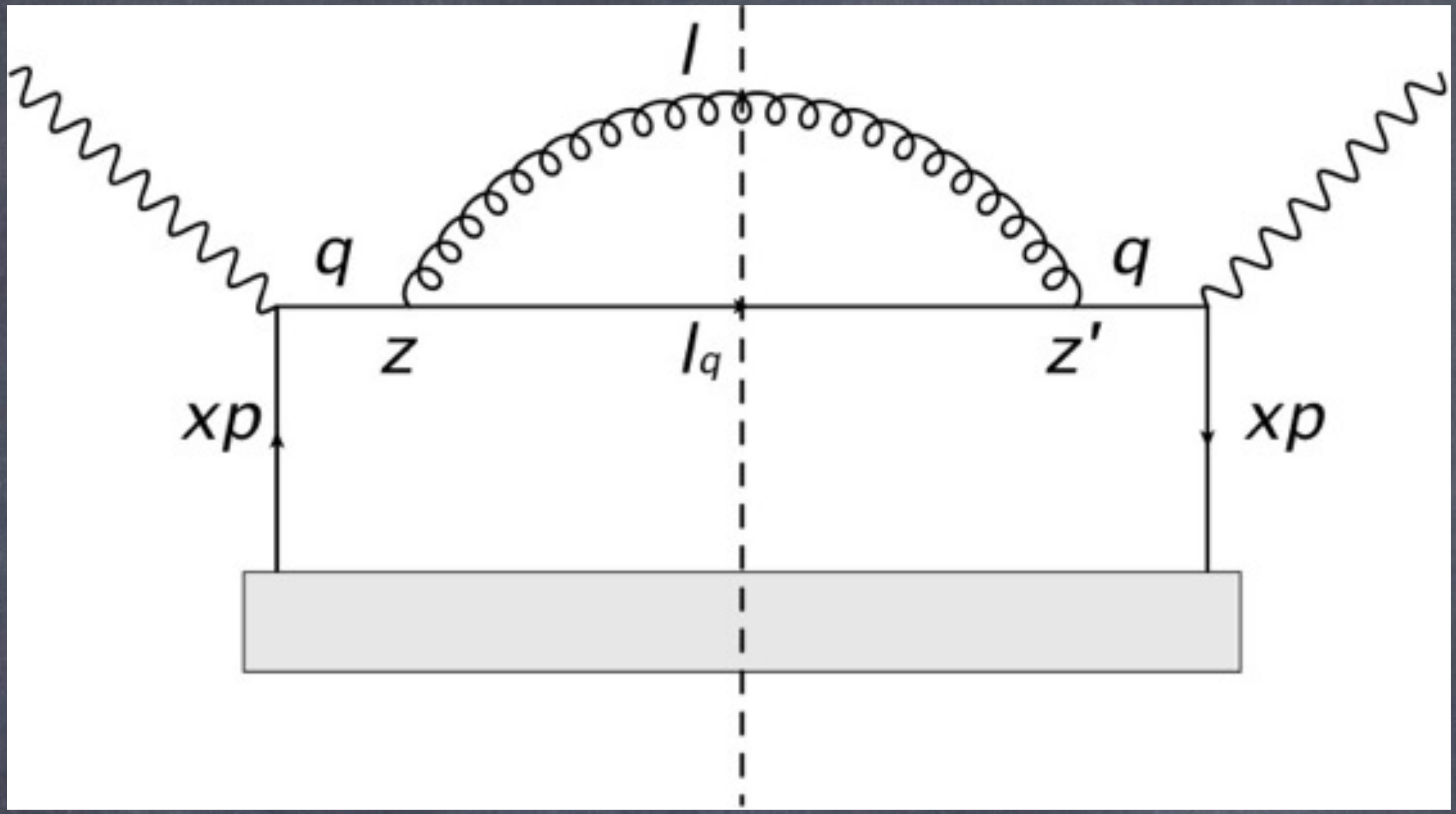
$$e^{i\bar{q}^+ \delta y^-} e^{i\delta q^+ \bar{y}^-}$$



Use hard emissions to denote the parton's length travelled

Consider one emission and q+

$$\bar{z} = \frac{z + z'}{2}$$



$$\delta z = z - z'$$

what is the role of z and z' ?

$$\int_0^\infty d^4\bar{z}\,\exp\left[i(\delta q)\bar{z}\right] \qquad \int d^4\delta z\,\exp\left[i\delta z(l + l_q - q)\right]$$

δq is the uncertainty in q,

How much uncertainty can there be ?

To be sensible: $\delta q \ll q$

we assume a Gaussian distribution around q^+

And try different functional forms of the width

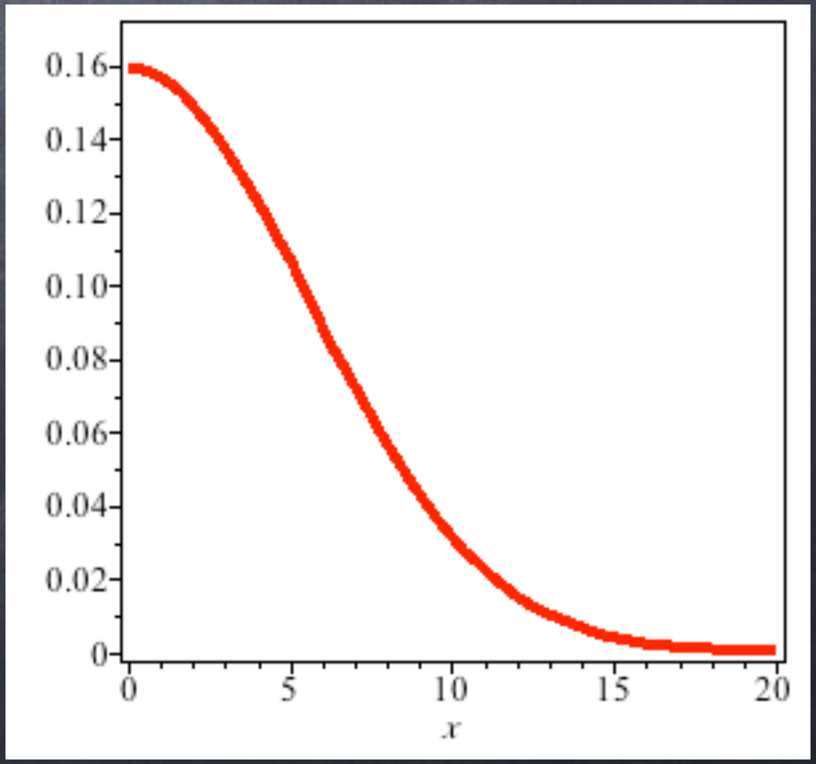
We set the form by insisting $\langle\tau\rangle = 2q^-/(Q^2)$

to obtain the z^- distribution only need to assume a δq^+ distribution

$$\rho(\delta q^+) = \frac{e^{-\frac{(\delta q^+)^2}{2[2(q^+)^2/\pi]}}}{\sqrt{2\pi[2(q^+)^2/\pi]}}$$

A normalized Gaussian with a variance $2q^+/\pi$

FT gives the following distribution in distance



Now we sample the Sudakov

$$S = e^{-\int_{t_0}^{t} \frac{dQ^2}{Q^2} \frac{\alpha_S}{2\pi} \int dy P(y)(1+K)}$$

K=0 in vacuum, the Guo-Wang kernel is

$$K = \int_{t_i}^{t_i+\tau_f} d\zeta \frac{\hat{q}}{l_\perp^2} \left[2 - 2\cos\left(\frac{\zeta}{\tau_f}\right)\right]$$

Use mean value $\tau_f = \dfrac{l_\perp^2}{2q^- y(1-y)}$

Now with the sampled value of Q and y, get the τ

This is the splitting distance !

Consider a jet moving through a QGP Brick

We now construct a Sudakov with the constraint

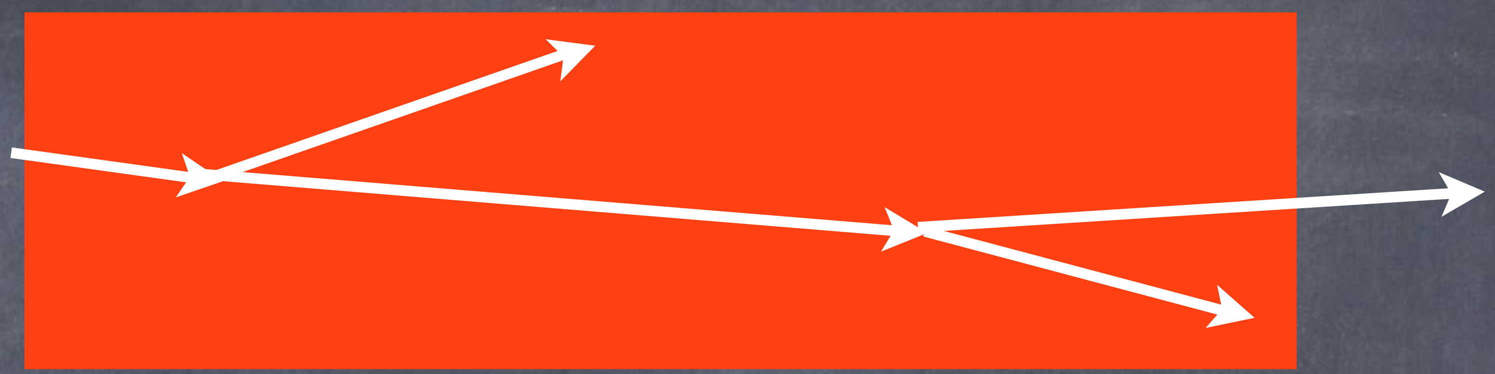
$$\frac{Q_0^2}{Q^2} < z < 1 - \frac{Q_0^2}{Q^2}$$

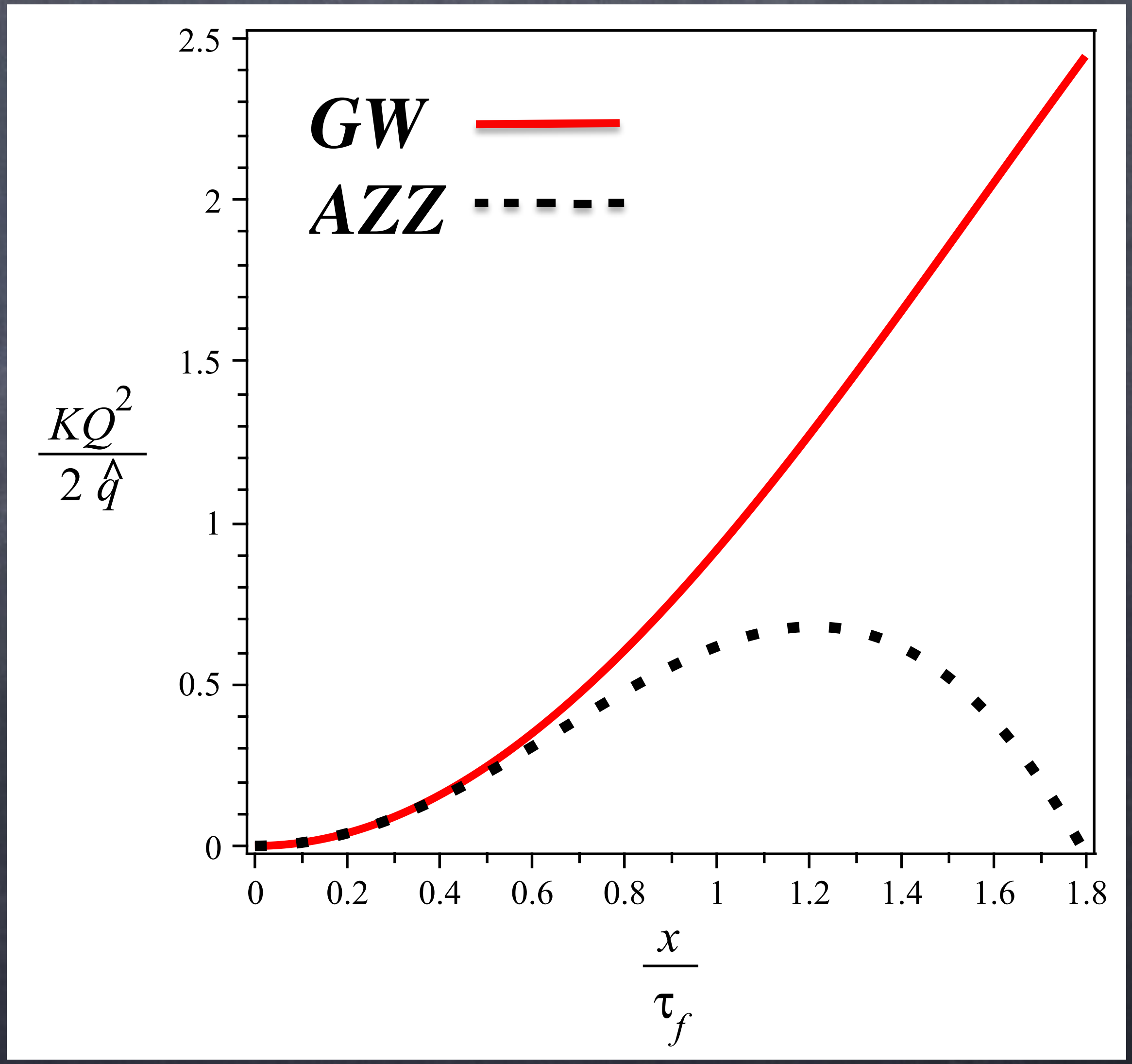
Have a distribution of locations of splittings

length dependent transverse broadening (added afterwards)

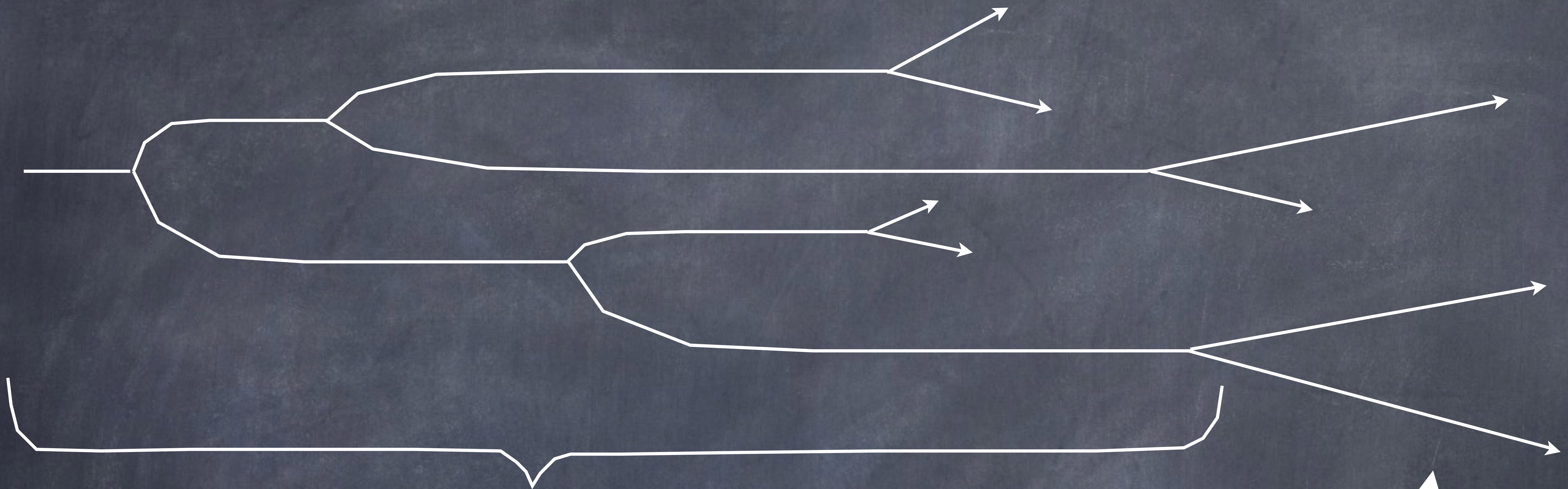
length dependent drag loss added afterwards

Partons whose virtuality drops below Q_0 = 1 GeV are no longer branched.





Note: Shower has no transverse location info.



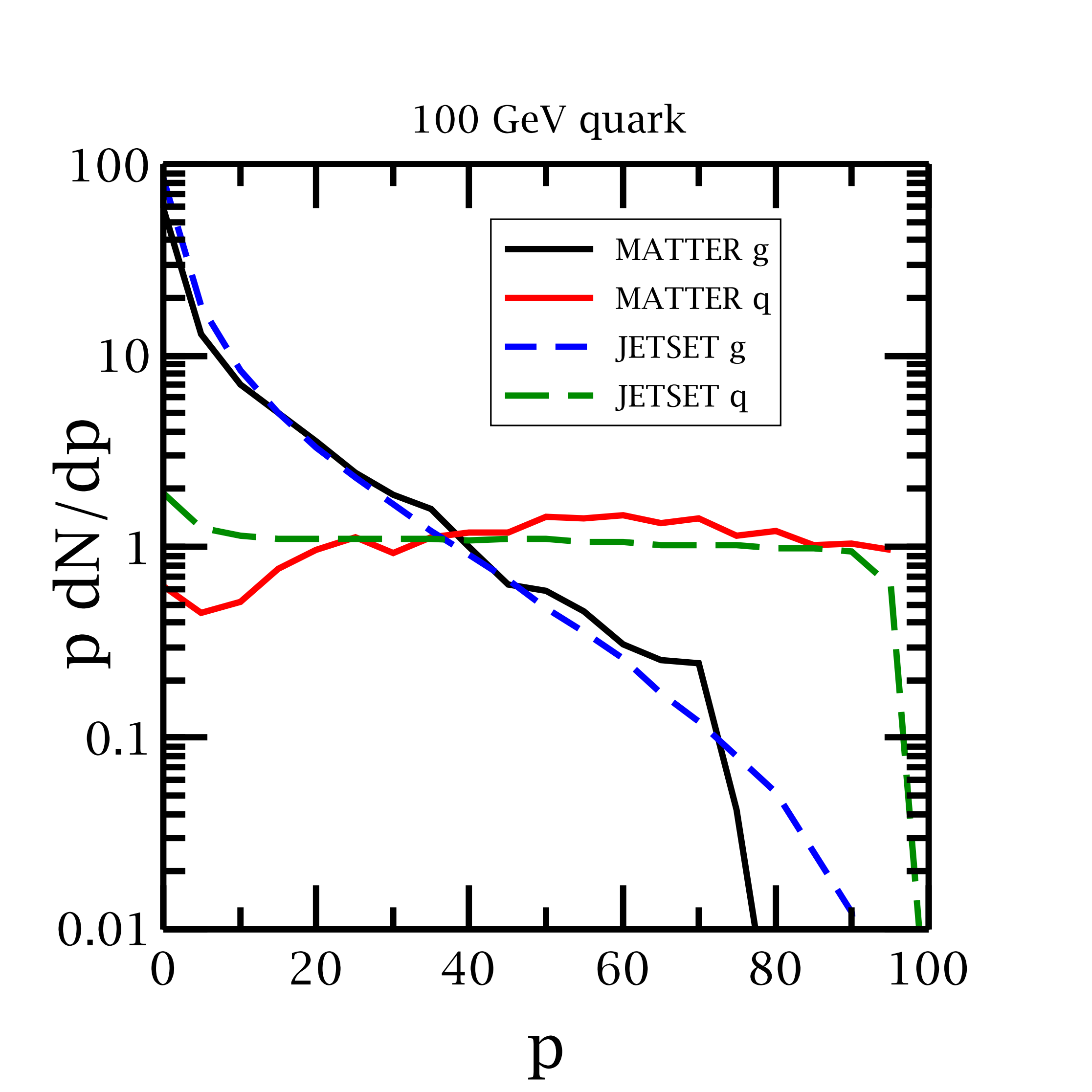
Longitudinal location of splits retained exactly

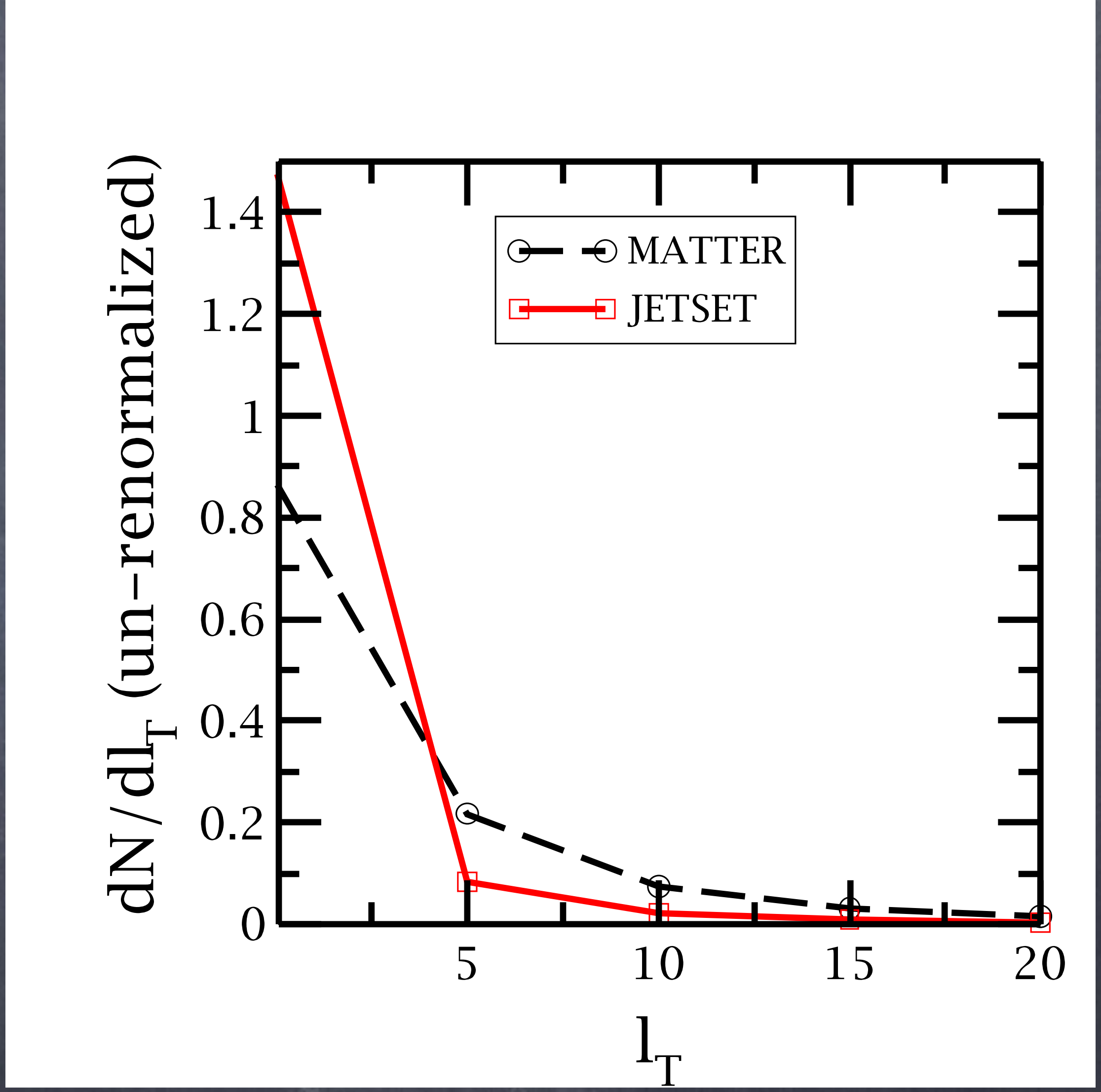
Accumulated transverse momentum added to final state particles and then propagated at speed of light from last split

Final shower is fed to Recombination module

Comparisons with PYTHIA

Distribution of 1 GeV quarks and gluons from 100 GeV quark





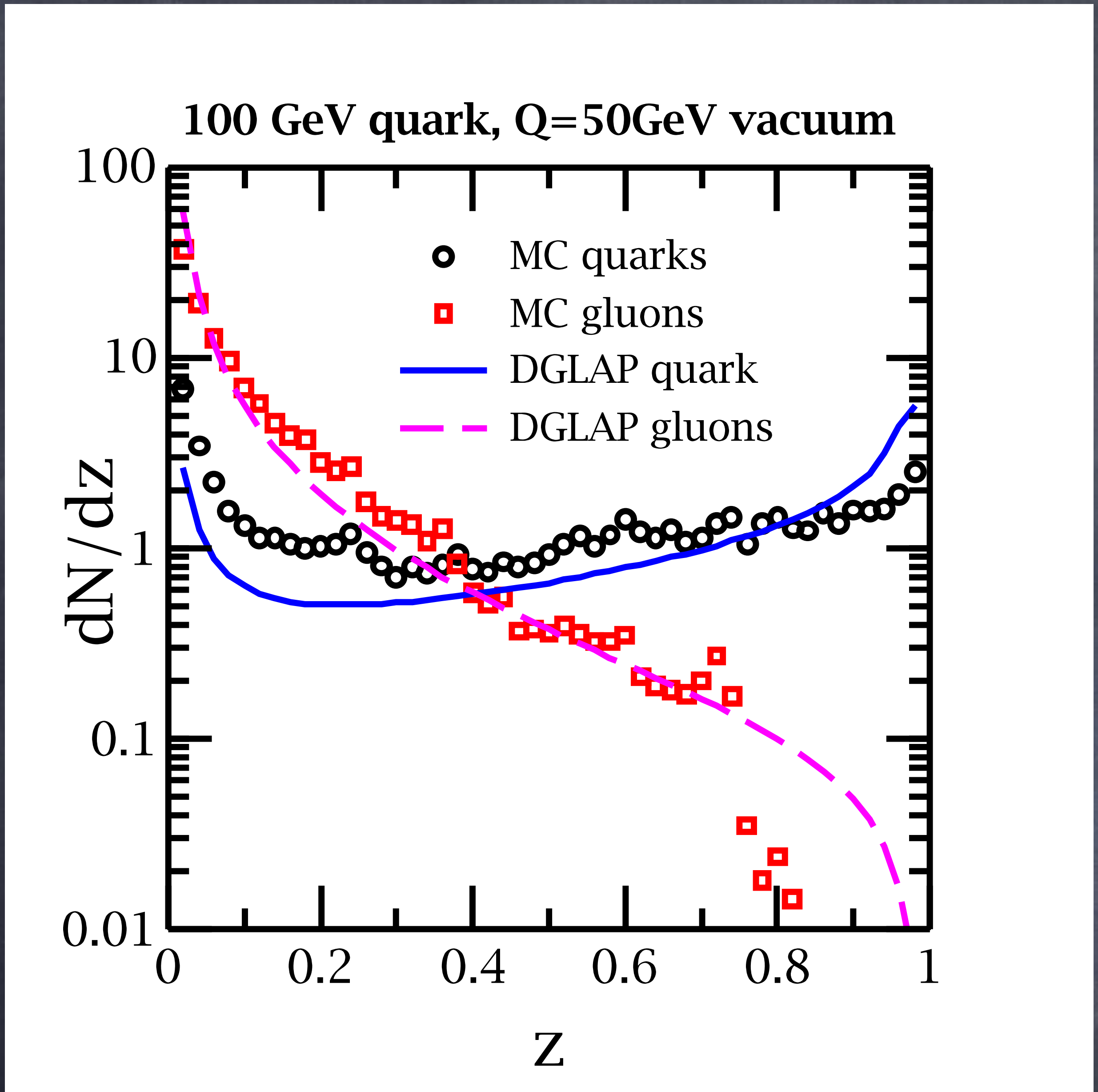
JETSET uses E ratio for z. MATTER uses light-cone momentum (corrections at small and large z)

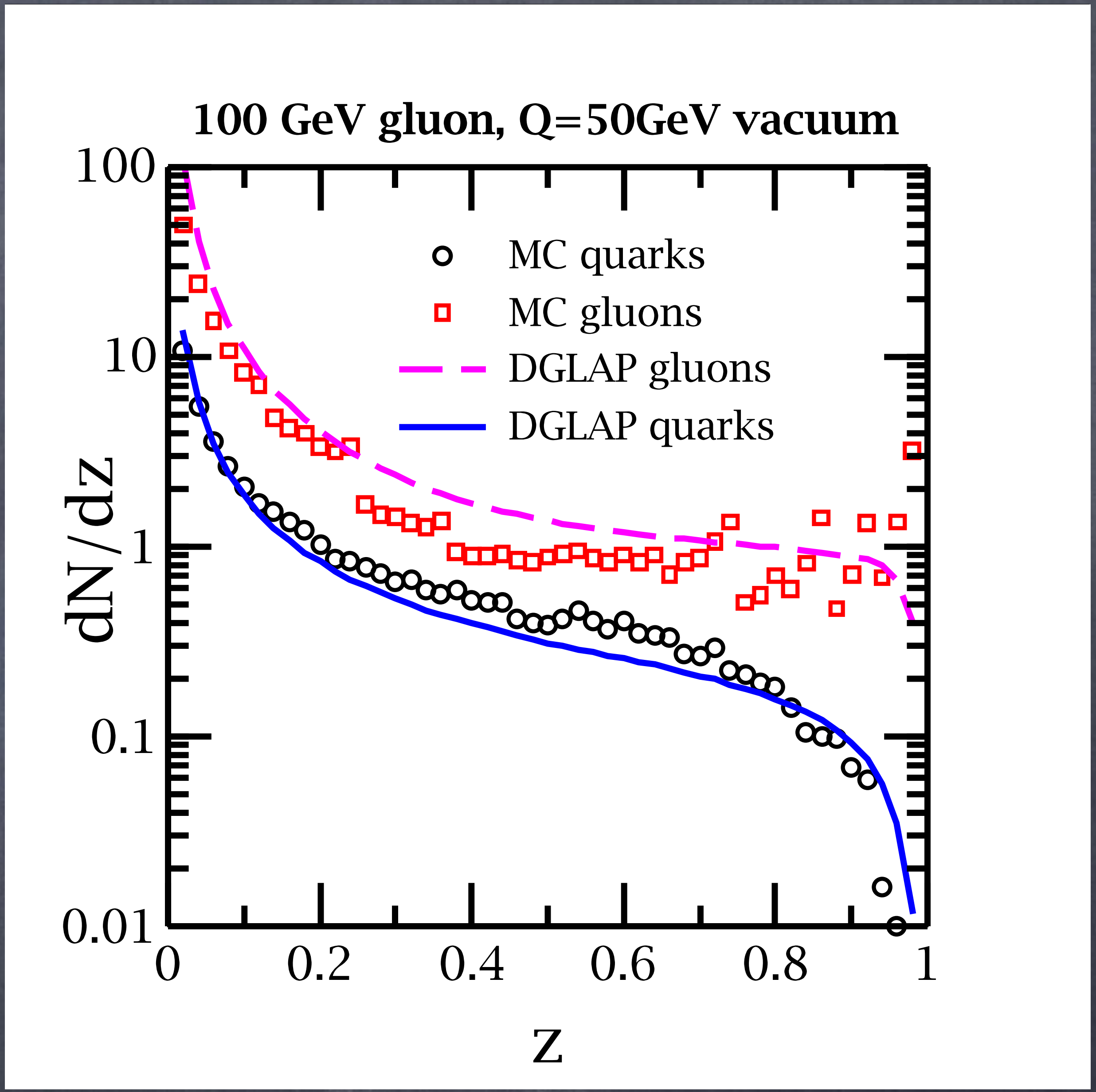
MATTER uses

$k_T^2 = z(1-z)t - m_1^2 - m_2^2$

JETSET uses an intermediate value (future upgrade)

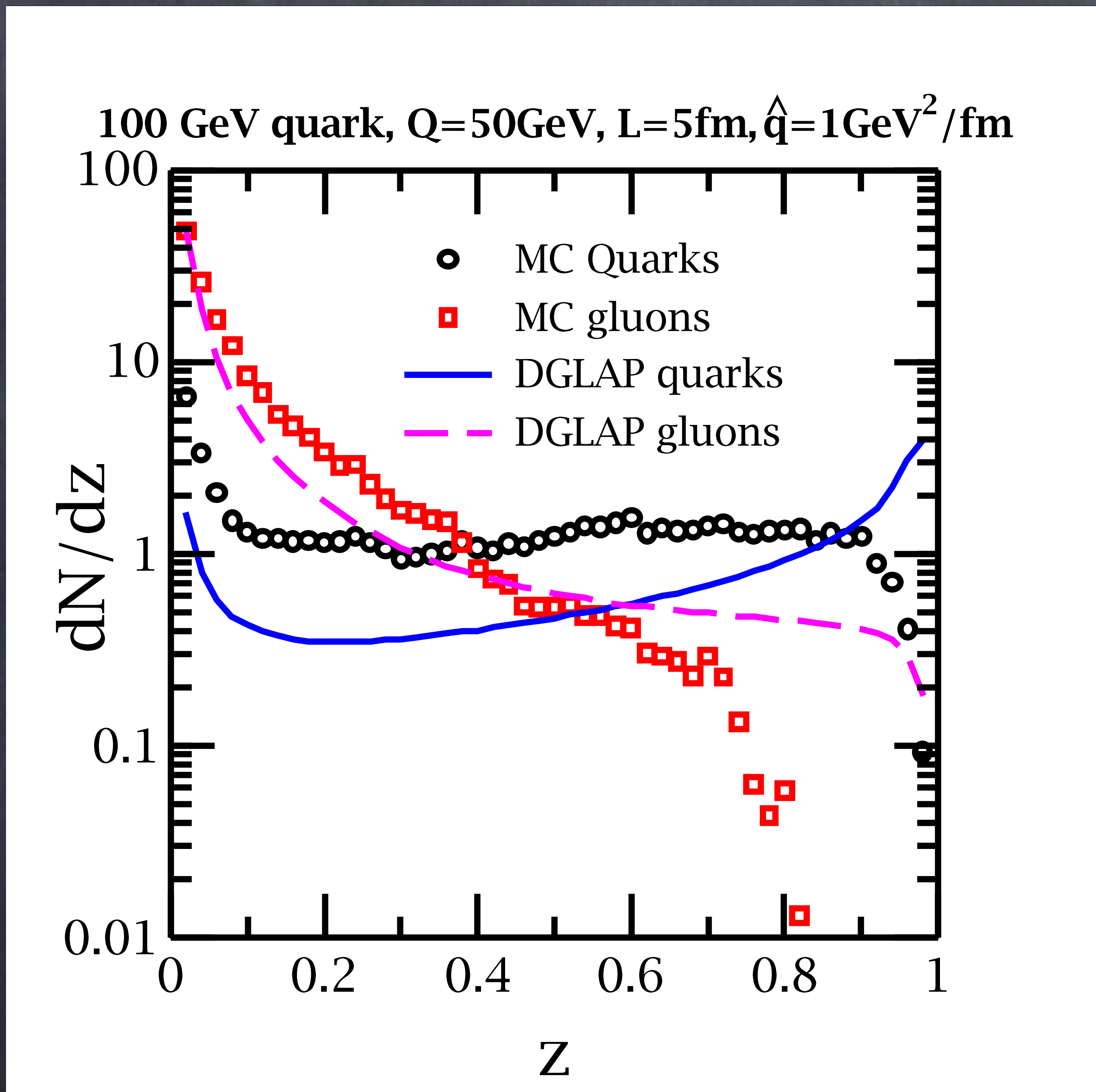
Comparison between MC and DGLAP

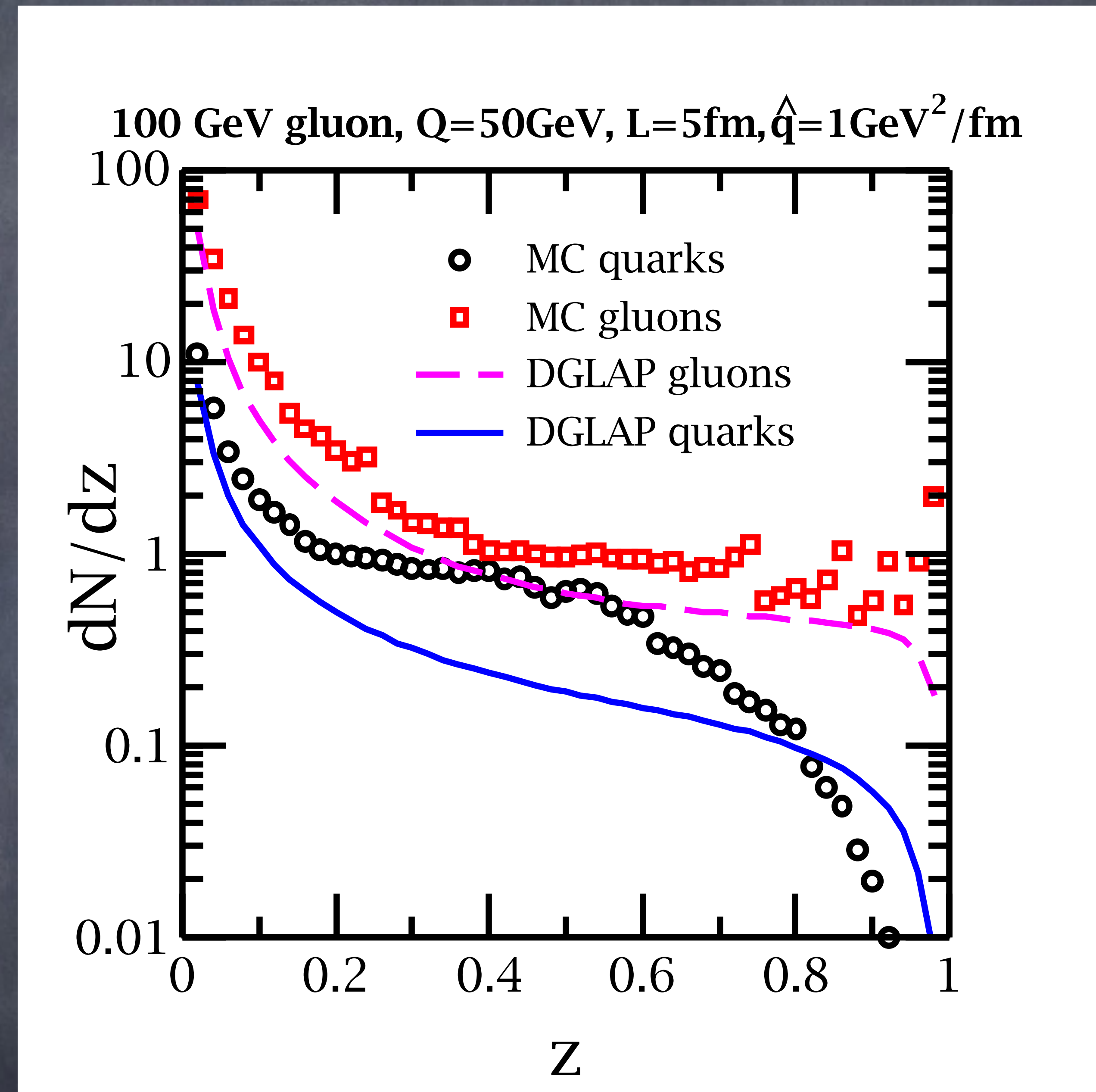




Same code, set $\hat{q} = 0$

Decent comparison in the medium

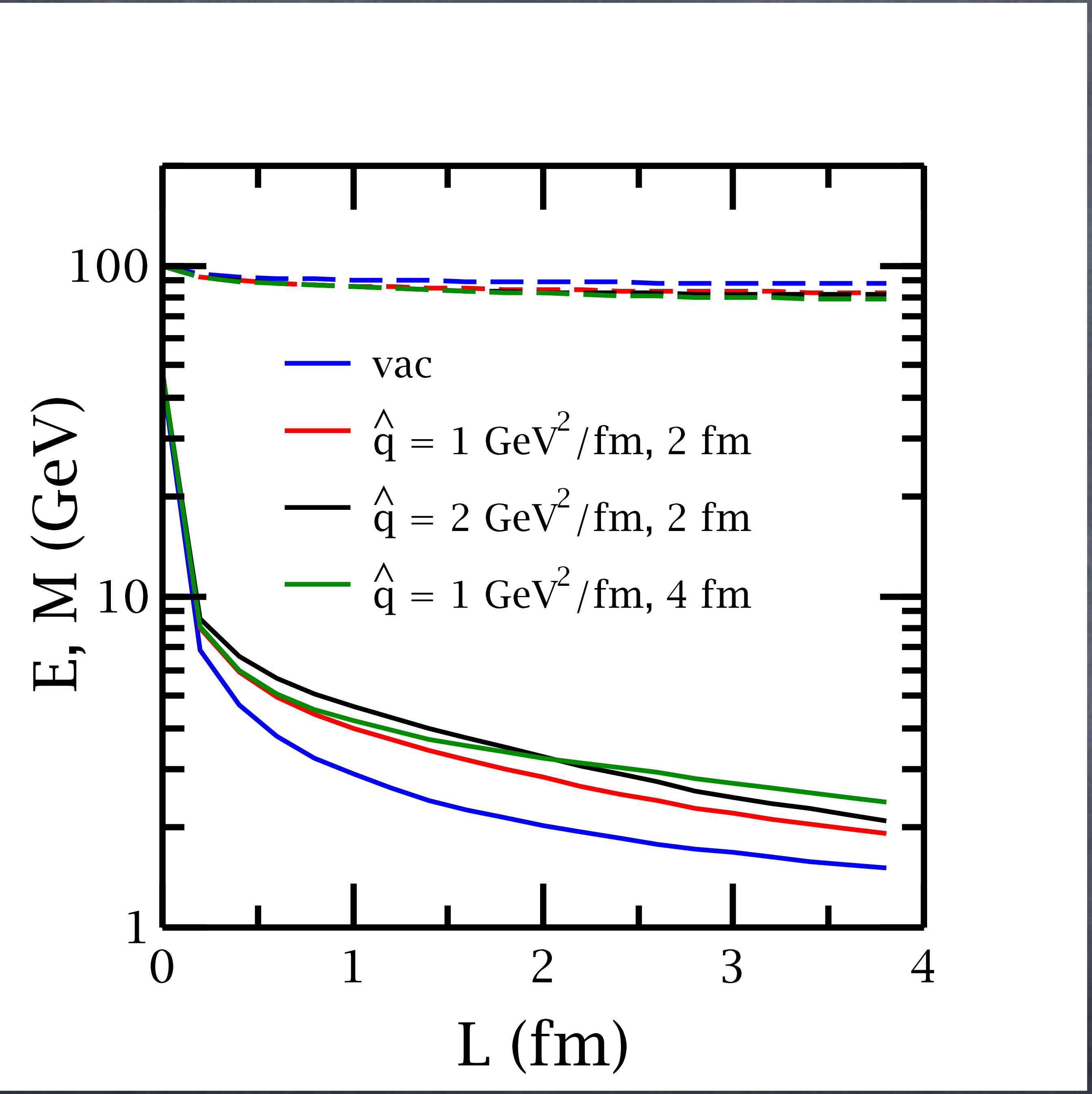




Note that we are evolving a delta function
DGLAP is unstable for this case

Recent Insights from MATTER

Virtuality or mass drops much more quickly than Energy

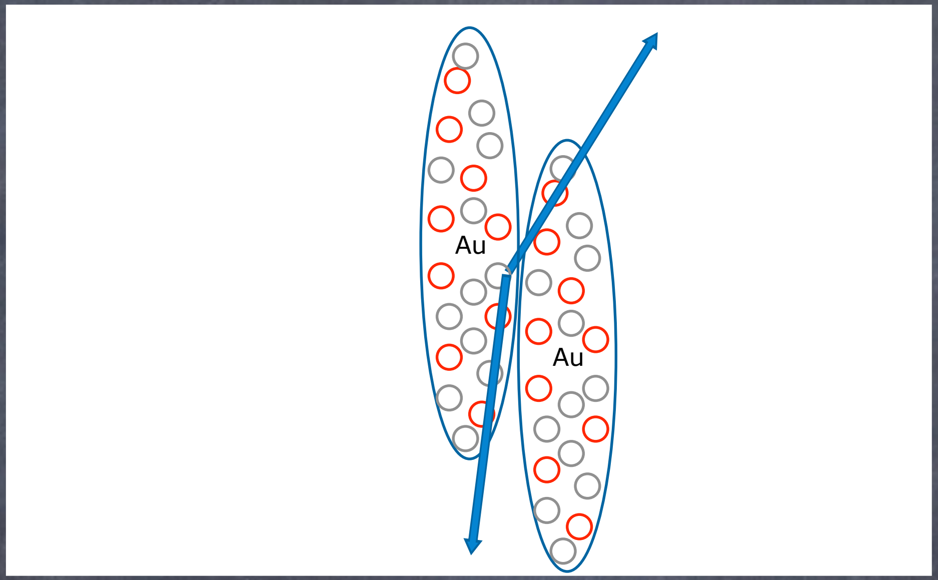


Medium slows down the drop in virtuality.

For long static media, one moves from the DGLAP regime to the BDMPS regime (for the leading parton).

What remains to be done?

1) Data from initial state + PYTHIA MC fed to both hydro and jet energy loss module



2) Shower modification carried out based on $\hat{q}$ and $\hat{e}$ in fluid medium

3) 1 GeV partons then fed to RECO code.

Other projects at WSU

Heavy-quark energy loss using $\hat{q}$ and $\hat{e}$

NLO calculation of next-to-leading twist in single hadron inclusive annihilation in a QGP brick.

Resummation of multiple scatterings in all twist expression

Calculation of $\hat{q}$ on lattice in quenched SU(3)

Updates from the LBNL group

(1) Completed the update on elastic scattering part going from small angle approximation of the cross section to full set of elastic scattering including annihilation and flavoring changing processes.

(2)Completed the implementation of HT gluon radiation, studied gamma-jet asymmetry in Pb+Pb collisions at LHC. IN the process of studying single and dijet suppression at RHIC and LHC

(3)Close to finish event-by-event coupled LBT-hydro coupled simulation

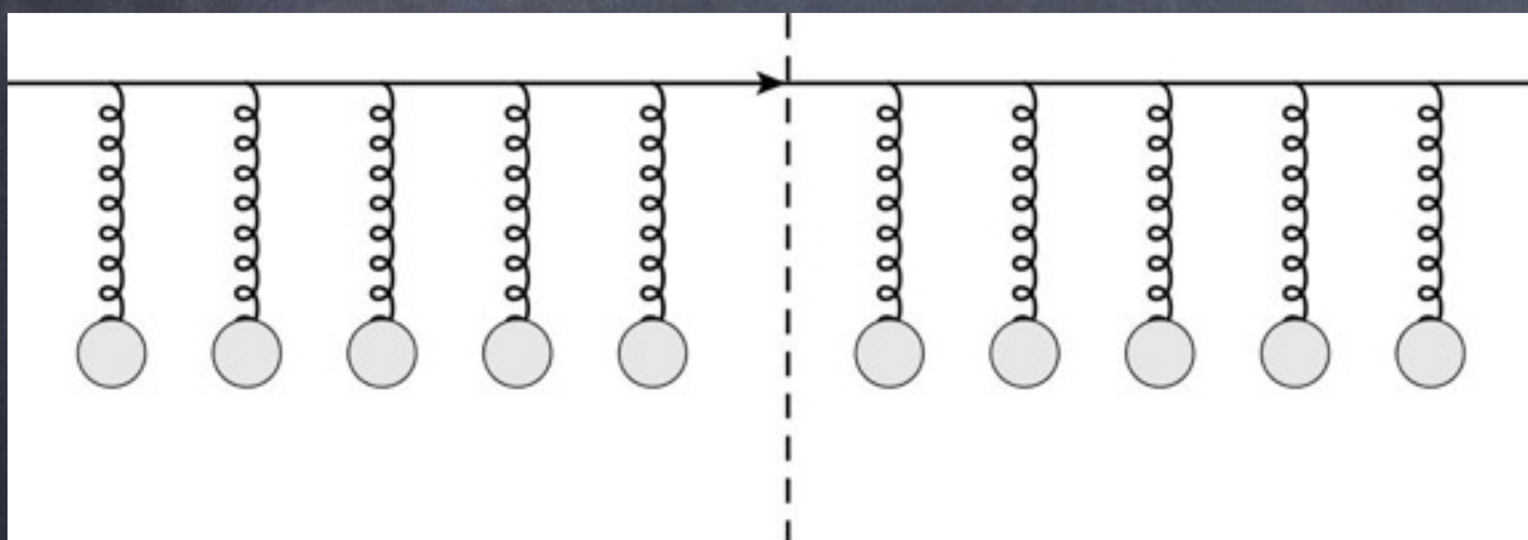
(4)Will work with TAMU group on implementing parton recombination model for hadronization

Thank you for your attention!

Background on momentum components

A parton in a jet shower, has momentum components

q = (q^-,q^+,q_T) = (1,λ^2,λ)Q, Q: Hard scale, λ << 1, λQ >> Λ_{QCD}



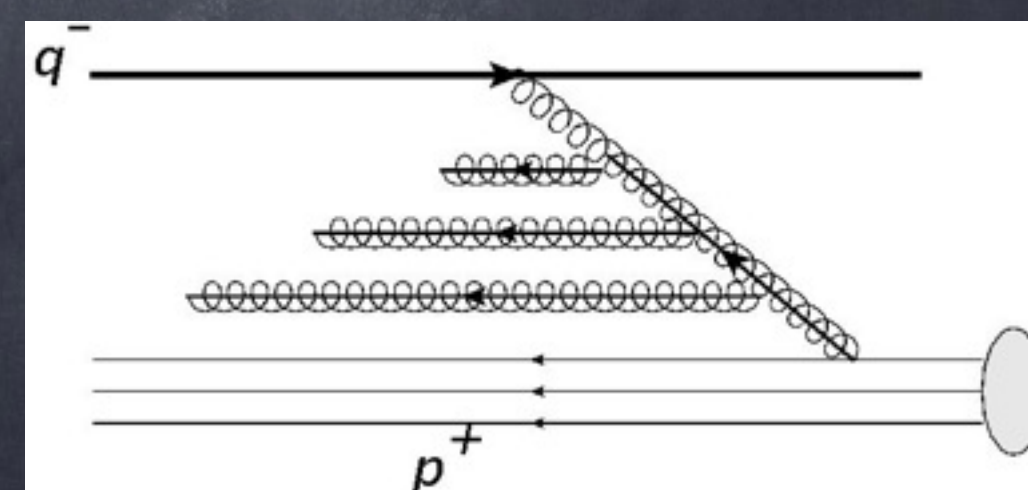
$$p^+ = \frac{p^0 + p_z}{\sqrt{2}}$$

$$p^- = \frac{p^0 - p_z}{\sqrt{2}}$$

hence, gluons have

$$k_\perp \sim \lambda Q, \qquad k^+ \sim \lambda^2 Q$$

could also have $k^- \sim \lambda Q$



Idlilbi, Majumder 2008