A wake of color medium by a fast parton

Ghi R Shin

With S. Bass and B. Mueller

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Predictions of upcoming winners for Nobel Prize In Physics

- For discovering accelerating cosmological expansion: Adam Riess, Saul Perlmutter, Brian Schmitt
- For formulating chaos theory: Mitch Feigenbaum, Edward Ott, James Yorke, and Celso Grebogi, Harry Swinney, Benoit Mandelbrot
- For the discovery and study of extrasolar planets: Alexsander Wolszczan, Dale Frail, Paul Butler, Geoffrey Marcy, Michael Mayor, Didier Queloz, David Lathan
- For discovering and developing carbon nanotubes: Sumio Iijima, Cees Dekker, Phaeton Avouris, Charles Lieber, Thomas Ebbeson
- For synthesizing superheavy elements: Peter Armbruster, Yhuri Oganessian, Sigurd Hofmann
- For formulating inflationary cosmology: Alan Guth, Paul Steinhardt, Andrei Linde
- For predicting, discovering, and developing negative-index metamaterials: Victor Veselago, John Pendry, David Smith, Xiang Zhang, Sheldon Schultz, Ulf Leonhardt
- For discovering and developing photonic crystals: Eli Yablonovitch, Shawn Lin, John Joannopoulis
- For discovering graphene: Andre Geim and Kostya Novoselov
- For studies on quantum nonlocality, entanglement, decoherence, and atom optics: Alan Aspect, Serge Harouche, Anton Zeilinger, Charles Bennett, Anton Zurek, David Pritchard, Joerg Schmiedmayer, David Wineland, Peter Zoller
- For achieving stopped light and electromagnetically induced transparency: Lene Hau, Ronald Walsworth, Mikhail Lukin, Stephen Harris, and Marlon Scully
- For predicting and demonstrating quark-gluon plasma: Miklos Gyulassy, Bill Zajc, Berndt Mueller
- For the development of the LED laser, Nick Holonyak; Shuji Nakamura, blue laser; Robert Hall, first semiconductor laser
- For the discovery of the top quark: Paul Grannis, Mel Schocket, William Carruthers
- Show repliesNone of the above... I think this will win (please specify)

Problems with PCC: heavy ion collisions

- Unknown parton distributions of nuclei: CTEQ, GRV & EKS, CGC
- So many unknown parameters: coupling constant, minimum momentum transfer, density, temperature, ….
- Unknown equations of motions: Elze and Heinz, Geiger, Jeon, …

- NEEDS a simple and understandable scheme which has minimal unknowns

BRICK problem

- Thermalized system of gluons, quarks and antiquarks, or quarks and gluons
- Well defined temperature or entropy
- Thermal cross section: much less controversal – natural cutoff for the minimal momentum transfer
- Might important in QGP or Heavy Ion Collisions

1. Initial distribution

- Gluon: $f_B(E,T) = \frac{C_g}{e^{\beta E}-1}\frac{E^2}{4\pi^2}$

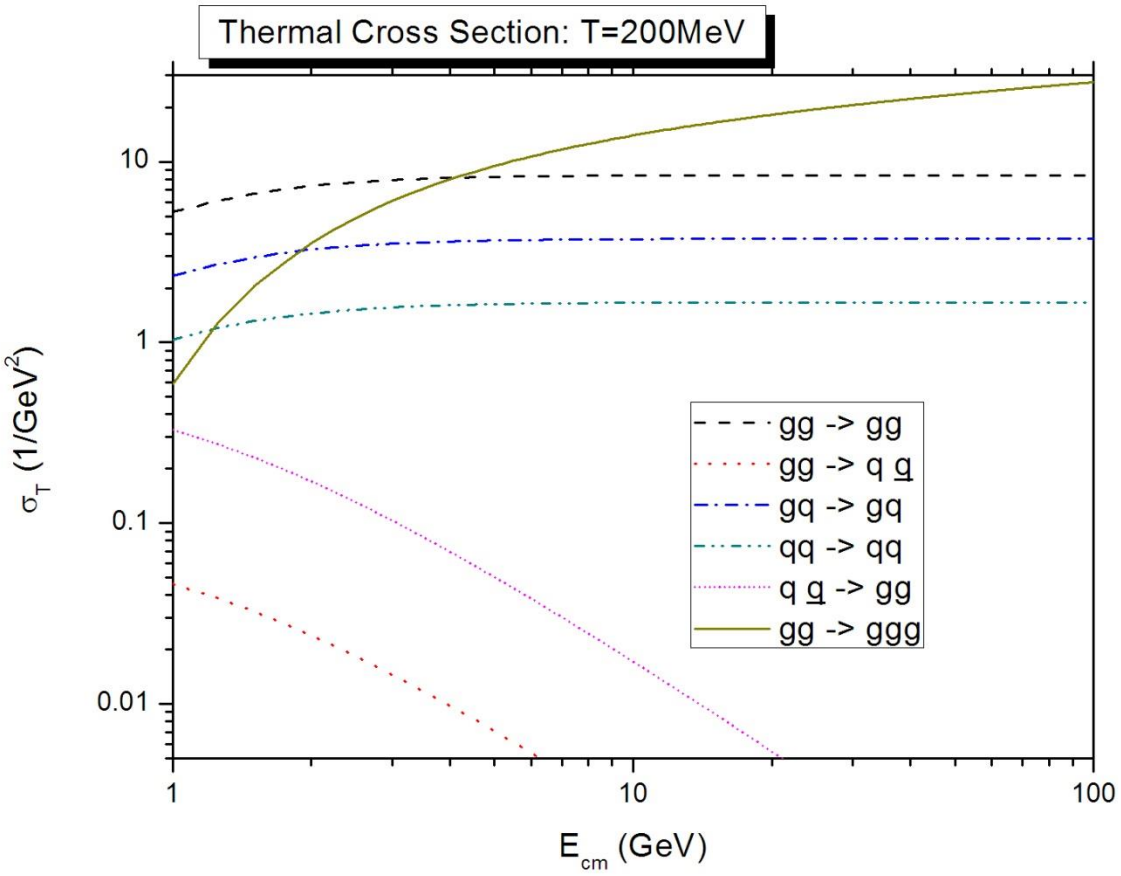
- (Anti)Quark: $f_F(E,T) = \frac{C_q}{e^{\beta E}+1}\frac{E^2}{2\pi^2}$

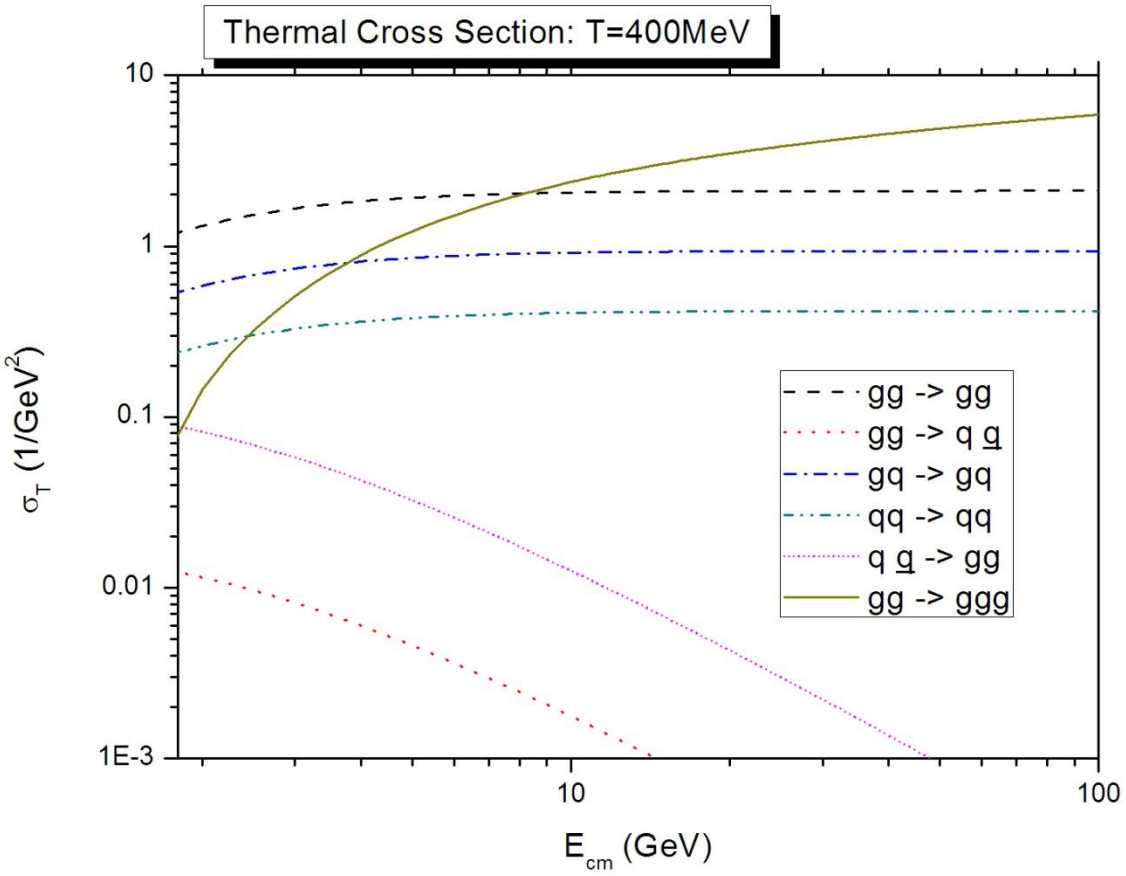
$$n(T) = \int_0^\infty f(E,T)dE$$

$$e(T) = \int_0^\infty Ef(E,T)\,dE$$

2. Cross Sections(thermal)

- gg->gg: $\frac{d\sigma}{dq_\perp^2} = 2\pi\alpha_s^2 \frac{9}{4} \frac{1}{(q_\perp^2+\mu_D^2)^2}$
- gg->qq: $\frac{d\sigma}{dq_\perp^2} = \frac{\pi\alpha_s^2}{6E_{cm}^2} \frac{1}{q_\perp^2+\mu_D^2}$
- gq->gq: $\frac{d\sigma}{dq_\perp^2} = \frac{2\pi\alpha_s^2}{(q_\perp^2+\mu_D^2)^2}$
- qq->qq: $\frac{d\sigma}{dq_\perp^2} = \frac{8\pi\alpha_s^2}{9} \frac{1}{(q_\perp^2+\mu_D^2)^2}$
- qq->gg: $\frac{d\sigma}{dq_\perp^2} = \frac{32\pi\alpha_s^2}{27E_{cm}^2} \frac{1}{(q_\perp^2+\mu_D^2)}$
- gg->ggg: $\frac{d\sigma}{dq_\perp^2 dy\, dk_\perp^2} = 2\alpha_s^3 C_A C_{gg} \frac{q_\perp^2}{(q_\perp^2+\mu_D^2)^2} \frac{1}{k_\perp^2+\mu_D^2} \frac{\theta(E_{cm}-m_\perp \cosh y)}{((k_\perp^2+q_\perp^2+\mu_D^2)^2-4k_\perp^2 q_\perp^2)^{1/2}}$


Thermal Cross Section: T=200MeV
10
1
0.1
0.01
σ_T (1/GeV^2)
1
10
100
E_{cm} (GeV)
gg -> gg
gg -> q q̲
gq -> gq
qq -> qq
q q̲ -> gg
gg -> ggg

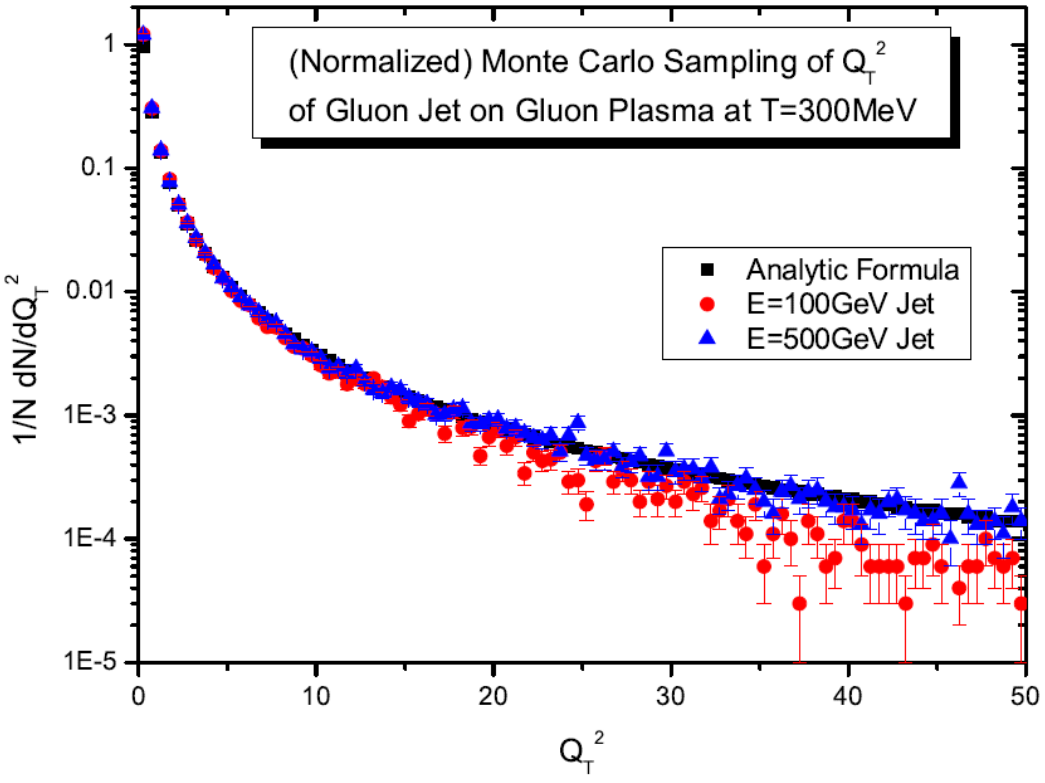

Thermal Cross Section: T=400MeV
10
1
0.1
0.01
1E-3
10
100
σ_T (1/GeV^2)
E_{cm} (GeV)
gg -> gg
gg -> q q̲
gq -> gq
qq -> qq
q q̲ -> gg
gg -> ggg

3. PCC

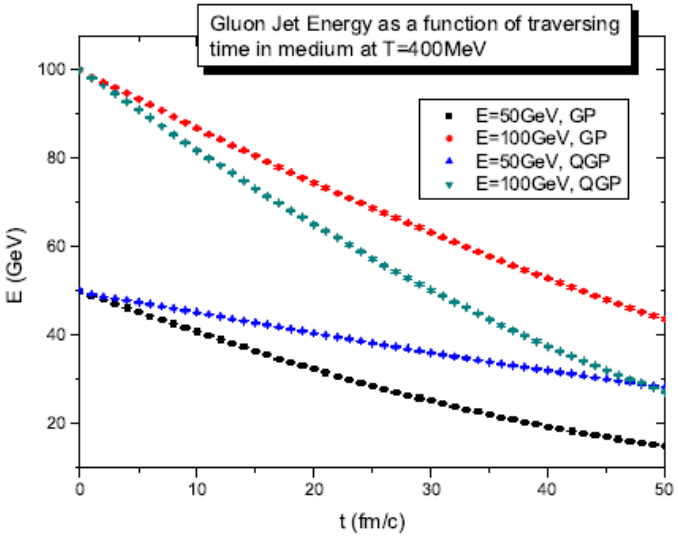
- NOT smart way but WORKS OK

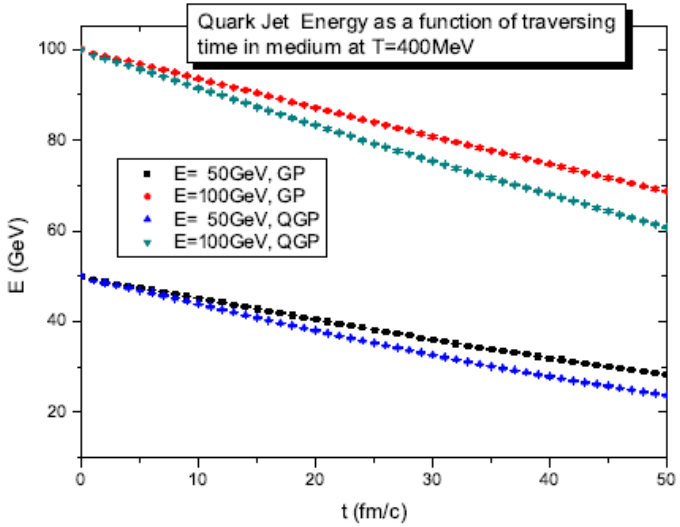
4. Results I: Fast Parton

- Monte Carlo sampling:

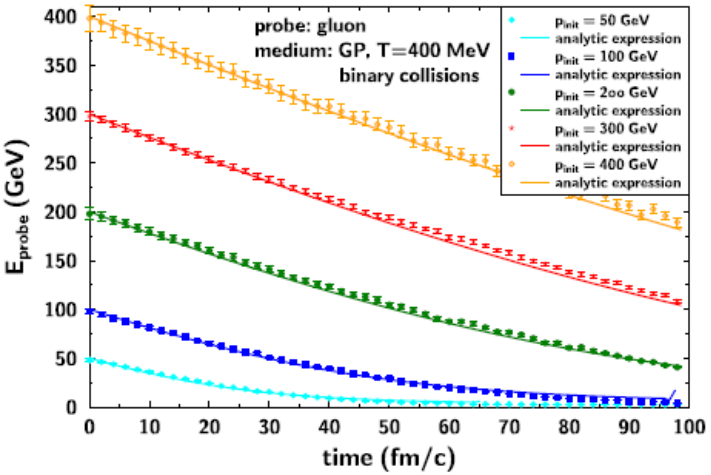


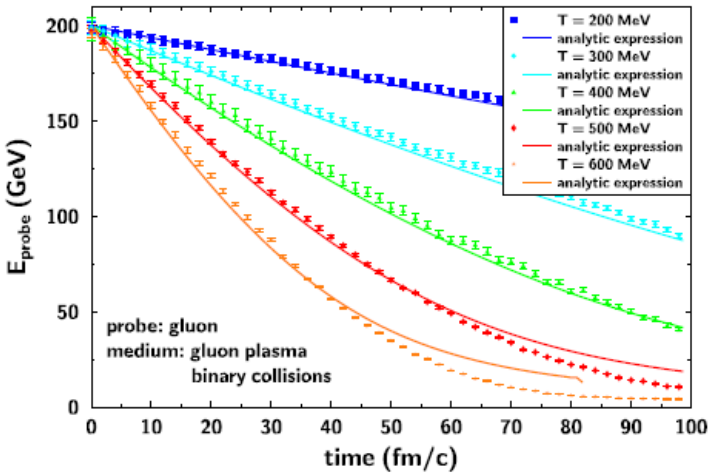
- Energy Loss:


Gluon Jet Energy as a function of traversing time in medium at T=400MeV
E=50GeV, GP
E=100GeV, GP
E=50GeV, QGP
E=100GeV, QGP
E (GeV)
t (fm/c)
100
80
60
40
20
0
10
20
30
40
50


Quark Jet Energy as a function of traversing time in medium at T=400MeV
E= 50GeV, GP
E=100GeV, GP
E= 50GeV, QGP
E=100GeV, QGP
E (GeV)
t (fm/c)
100
80
60
40
20
0
10
20
30
40
50

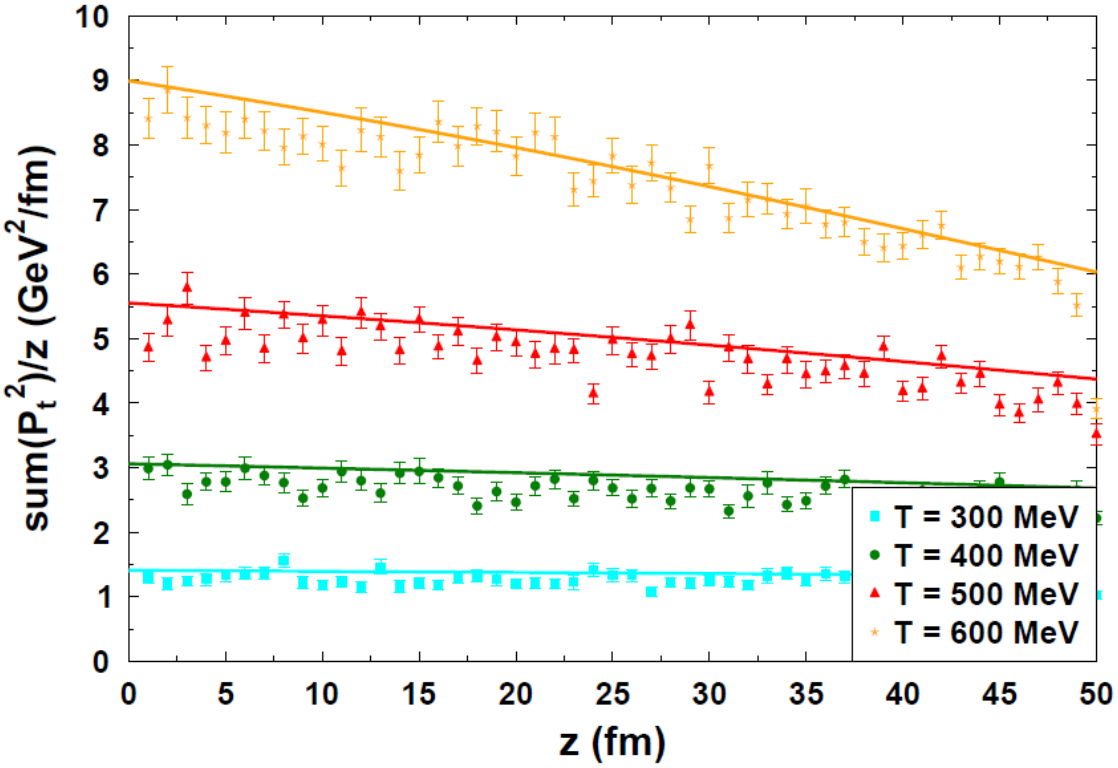
$$-\frac{dE}{dt} = \int \frac{d^3k}{(2\pi)^3} F_g(\vec{k};T) \int dq_\perp^2 (1-\cos\theta)\nu \frac{d\sigma}{dq_\perp^2}$$

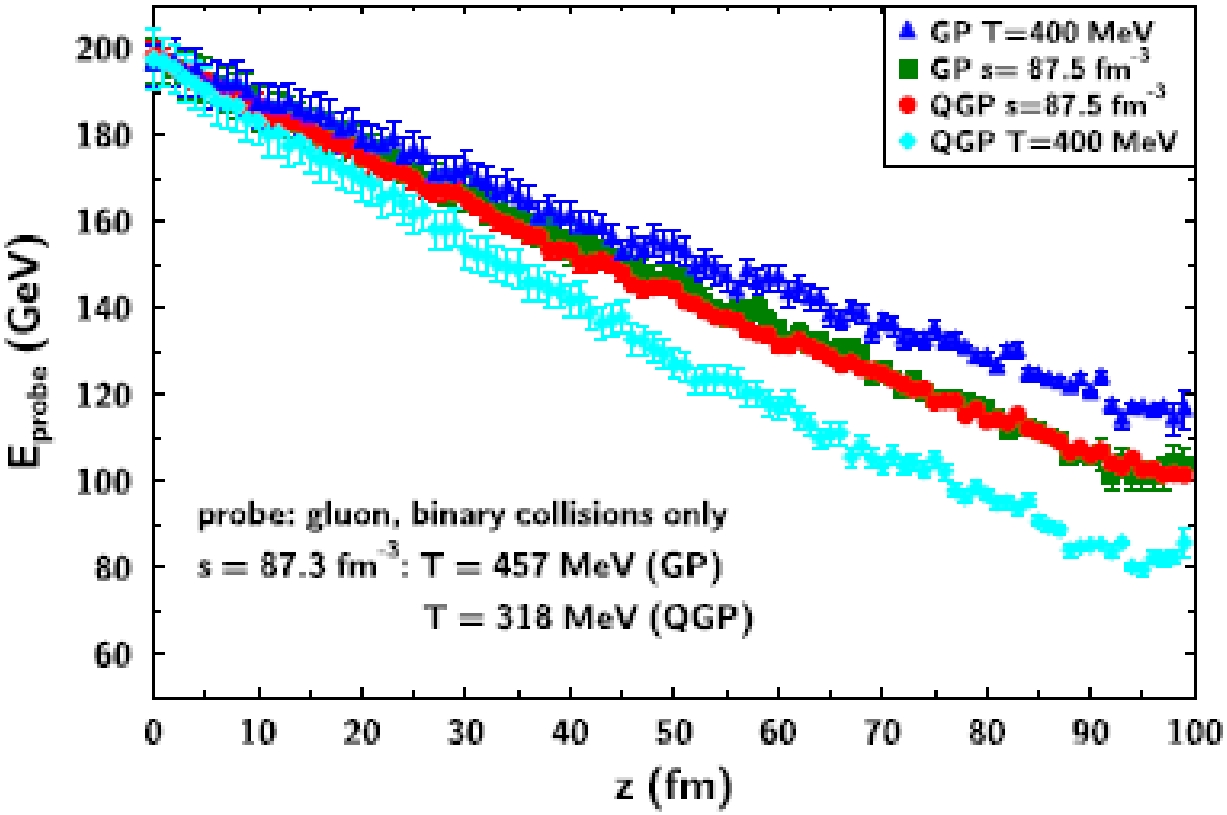




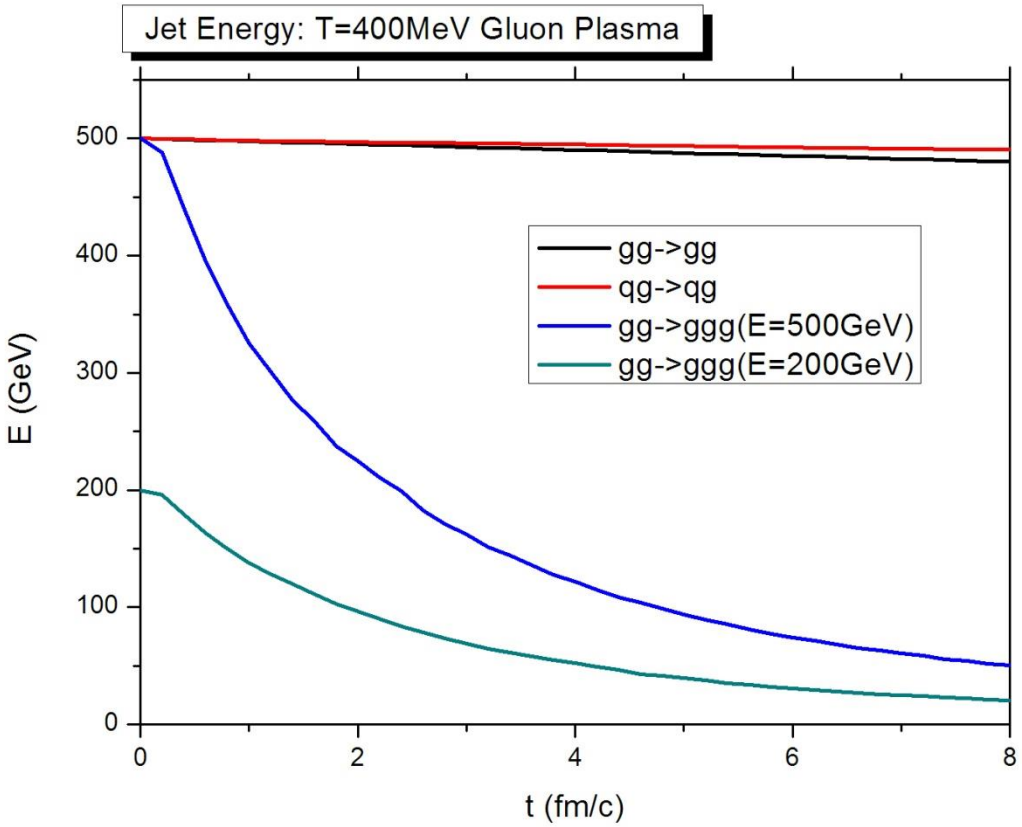
- Q_hat:

$$\hat{q}(\Lambda) \approx \alpha_s T m_D^2 \ln\left(\frac{T^2}{m_D^2}\right) + 4\pi \alpha_s^2 \mathcal{N} \ln\left(\frac{\Lambda^2}{T^2}\right)$$

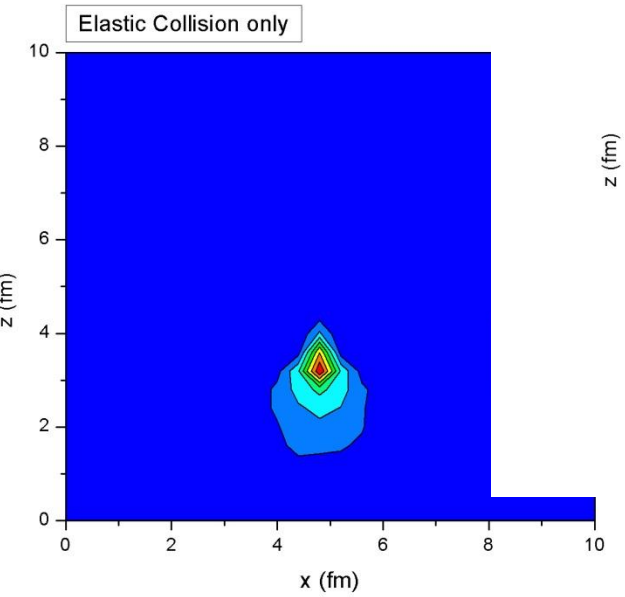


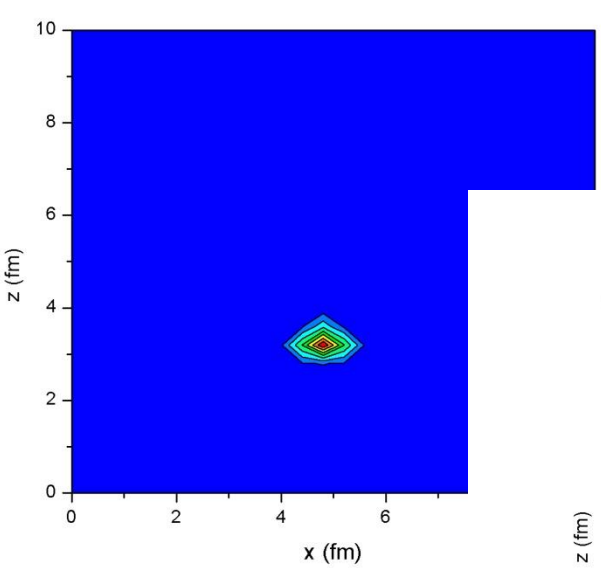

GP T=400 MeV
GP s= 87.5 fm^{-3}
QGP s=87.5 fm^{-3}
QGP T=400 MeV
probe: gluon, binary collisions only
s = 87.3 fm^{-3}: T = 457 MeV (GP)
T = 318 MeV (QGP)
E_{probe} (GeV)
z (fm)
200
180
160
140
120
100
80
60
0
10
20
30
40
50
60
70
80
90
100

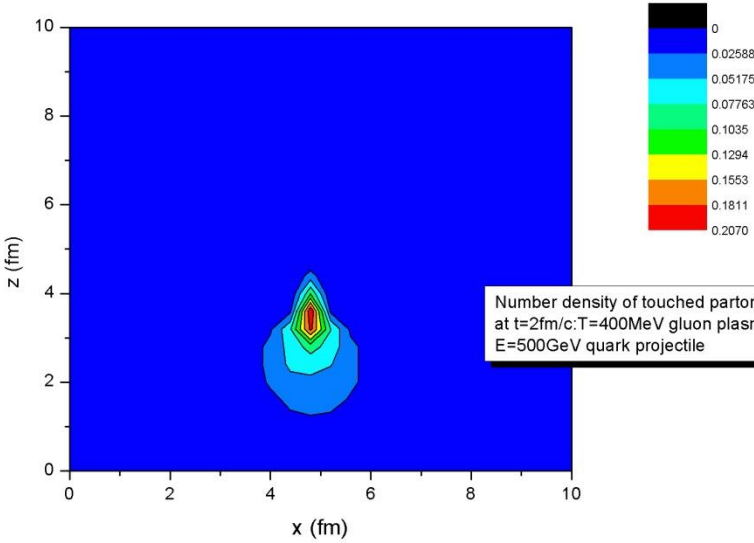
5. Results II: Medium Response

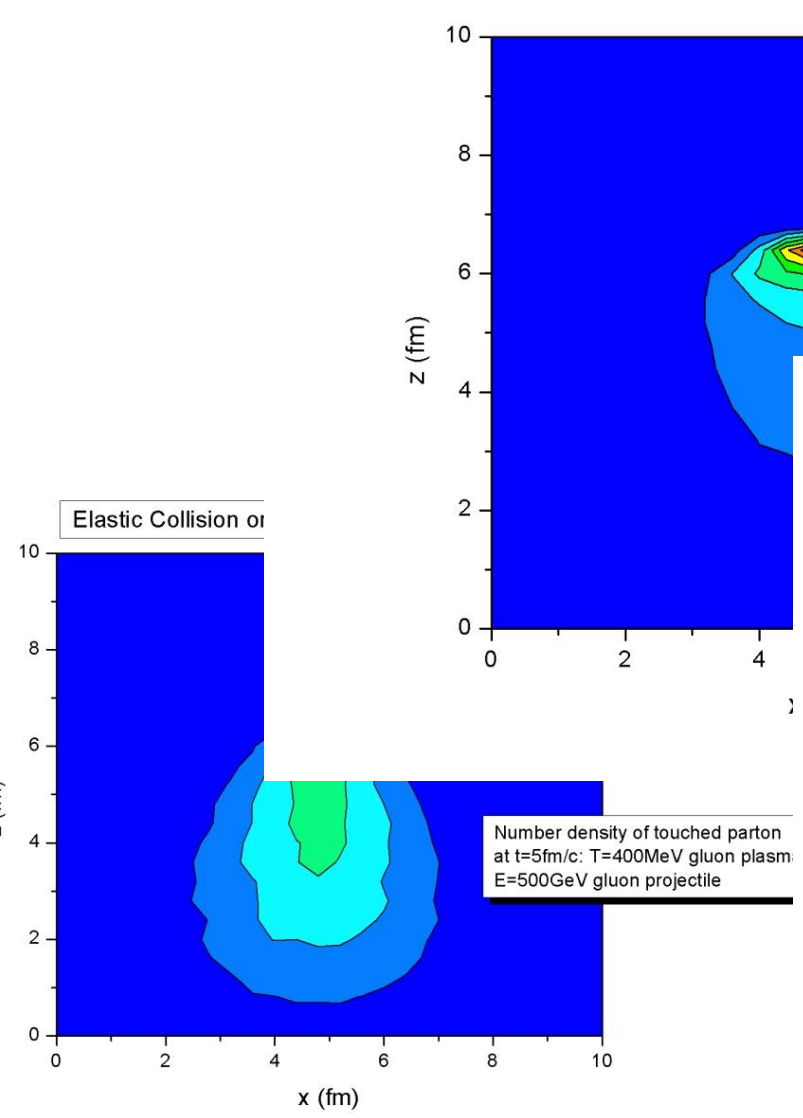


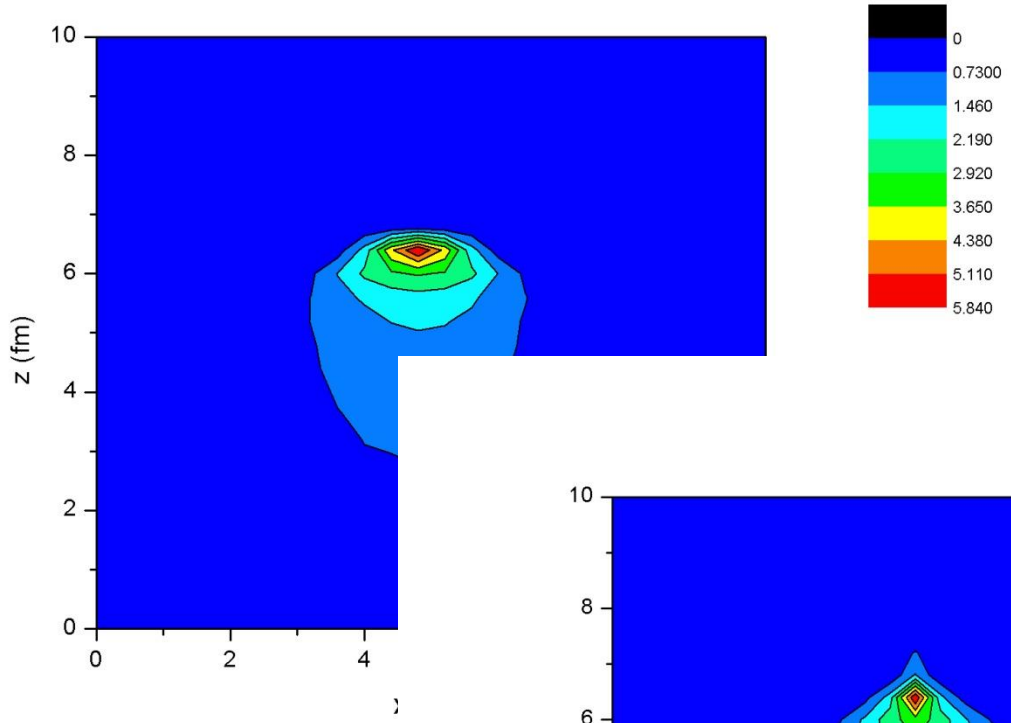
- Number density:

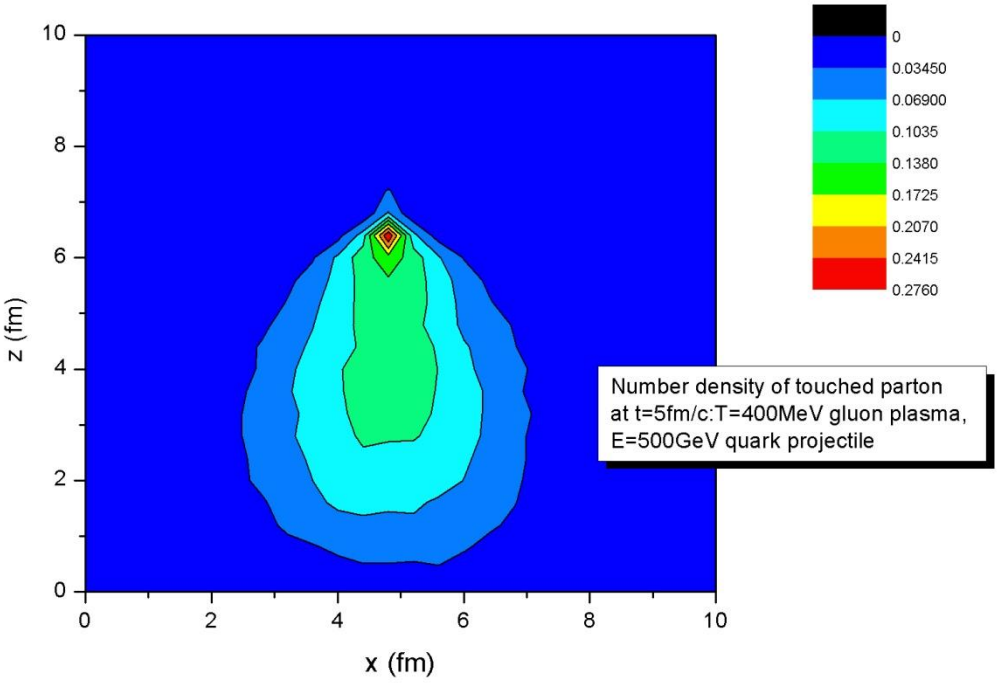


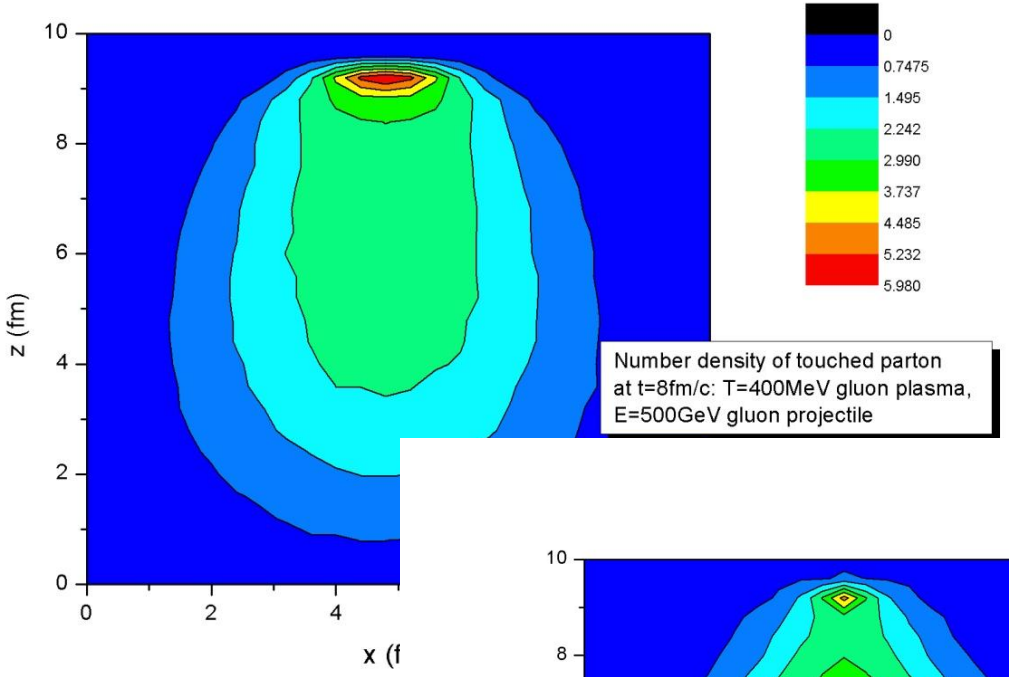


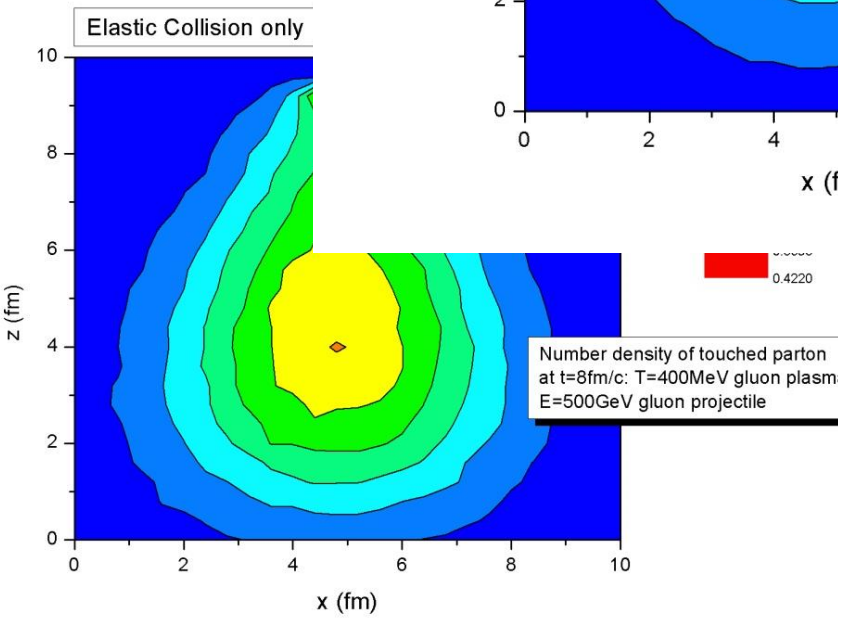


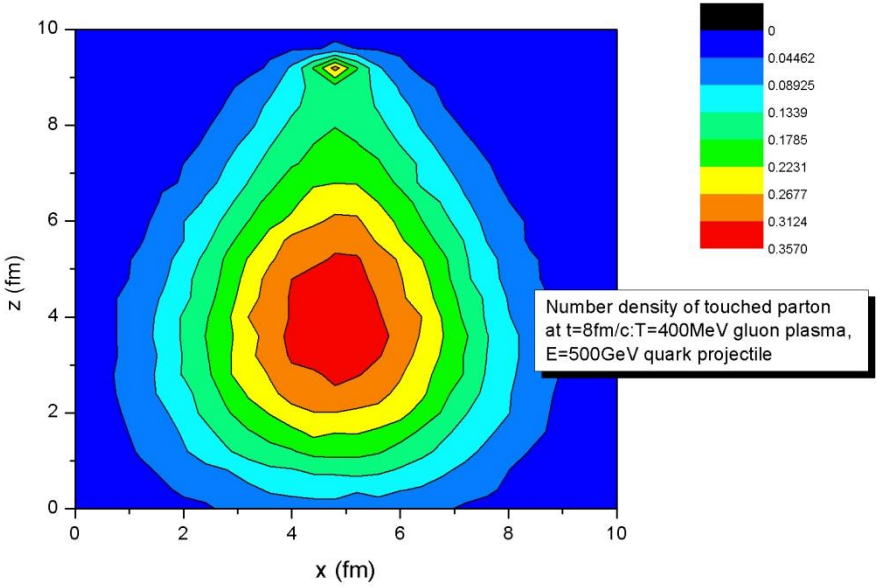

Elastic Collision o
Number density of touched parton
at t=5fm/c: T=400MeV gluon plasm
E=500GeV gluon projectile
x (fm)
z (fm)
0
2
4
6
8
10


0
0.7300
1.460
2.190
2.920
3.650
4.380
5.110
5.840


Number density of touched parton
at t=5fm/c:T=400MeV gluon plasma,
E=500GeV quark projectile
x (fm)
z (fm)
0
0.03450
0.06900
0.1035
0.1380
0.1725
0.2070
0.2415
0.2760


0
0.7475
1.495
2.242
2.990
3.737
4.485
5.232
5.980
z (fm)
x (f
Number density of touched parton
at t=8fm/c: T=400MeV gluon plasma,
E=500GeV gluon projectile


Elastic Collision only
0.4220
z (fm)
x (fm)
Number density of touched parton
at t=8fm/c: T=400MeV gluon plasm
E=500GeV gluon projectile


0
0.04462
0.08925
0.1339
0.1785
0.2231
0.2677
0.3124
0.3570
z (fm)
x (fm)
Number density of touched parton
at t=8fm/c:T=400MeV gluon plasma,
E=500GeV quark projectile

6. Concluding Remarks

- Good agreement with analytic formula in elastic scattering
- The medium responds differently with different temperature and projectile
- Do we see Mach cone or what are the angles?