Him 2006 May Meeting
ANDONG, 2006. 5. 20

Elliptic Flow and Jet Quenching at RHIC

Ghi R. Shin

Andong National University

gshin@andong.ac.kr

J.Phys G. 29, 2485/JKPS 43, 473

1. INTRODUCTION

Recent Conclusion of 1st RUNS at RHIC
(STAR, PHENIX, BRAHMS, PHOBOS):

STRONGLY INTERACTING QGP
of PERPECT FLUID:

1) Elliptic Flow can be explained by **HYDRODYNAMICS**.
2) Awayside **JET QUENCHING**.
3) and so on

- JUST MENTION:
  - Hydrodynamics can be applicable if **Momentum Isotropic** (P Arnold, J Lenaghan, GD Moore and LG Yaffe, nucl-th/0409068)
  - Is the Boltzmann equation(Kinetic theory) valid? **Maybe YES**. A. Mueller and DT Son showed that the dense classical field theory is equivalent to the Boltzmann equation(hep-th/0212198).

2. OVERVIEW of the TALK

1. Basic Algorithm of PARTON CASCADE CODE
2. INITIAL PHASE SPACE
3. SOME RESULTS
4. CONCLUSIONS

3. PCC

- **PCC:**

 1) Suppose we have N-particles.
 2) Let them evolve classically (but relativistically)
 3) Calculate the closest distance among the evolving particles just like QED.
 4) r_d < r_sigma : Collision
    r_d > r_sigma : NO collision
 5) Sort all the collisions to make the initial collision list.
 6) Let the particles on the list collide one by one and pick up new particles and momenta.
 7) calculate r_d for the new particle
 8) Update the collision list.
 9) Go to the step 6 until the final time.

4. INITIAL PHASE-SPACE

- Most important stuff of Kinetic theory is INITIAL PHASE SPACE DISTRIBUTION!!!

- Many kinds of IPS on the market.
    1) Factorization method:
    2) CGC Shattering method:

Factorization:

Pros: 1) will be good at LHC

2) include quarks, antiquarks

3) give reliable jets

Cons: 1) no soft partons

2) No good at RHIC

CGC Shattering:

pros: 1) can get soft partons

2) Good at RHIC

cons: 1) no quarks and antiquarks

2) seems to produce too many JETS

Factorization Method:

- The PARTON DISTRIBUTION of HIGH ENERGY Au:

$$f_{i/A}(x, Q^2) = f_{i/N}(x, Q^2) R_A(x, Q^2),$$

x : Bjorken Variable

Q : Transverse momentum,

N : Nucleon

i : Parton

$f_{i/N}$: The distribution of i-parton, GRV98 Function

R_A : Nucleon distribution of Nucleus A,

EKS98 Ratio Function

- Combine the distribution functions with (elastic) parton
  - parton cross section to get the primary partons:

$$\frac{dN^{jet}(\vec{b})}{dp_T dy} = K T(\vec{b}) \int dy_2 \frac{2\pi p_T}{\hat{s}} \sum_{ij,kl} x_1 f_{i/A}(x_1, Q^2) x_2 f_{j/A}(x_2, Q^2) \frac{1}{2} \sigma_{ij\to kl}(\hat{s}, \hat{t}, \hat{u})$$

b : impact parameter,

K : K-factor to include higher order,

T(b) : Overlap function,

$$T(\vec{b}) = \int d\vec{s}\, T_A(\vec{s}) T_B(\vec{b} - \vec{s})$$

T_A : Thickness function of the nucleus A.

- Note that the space-time are missing here!!

- Numbers of Produced Partons After Relativistic Heavy Ion Collisions(200 AGeV Au, Q_0 = 1.2 GeV)

b(fm)	Gluons	Quarks	Antiquarks	Total
0	3731	585	134	4450
1	3583	561	128	4272
2	3269	512	117	3898
3	2865	449	102	3416
4	2415	378	86	2879
5	1952	306	70	2328
6	1503	235	53	1791
7	1088	170	39	1297
8	727	114	26	867
9	433	67	15	515
10	215	33	7	255
11	75	11	2	88
12	10	1	0	11

CGC Shattering Method:

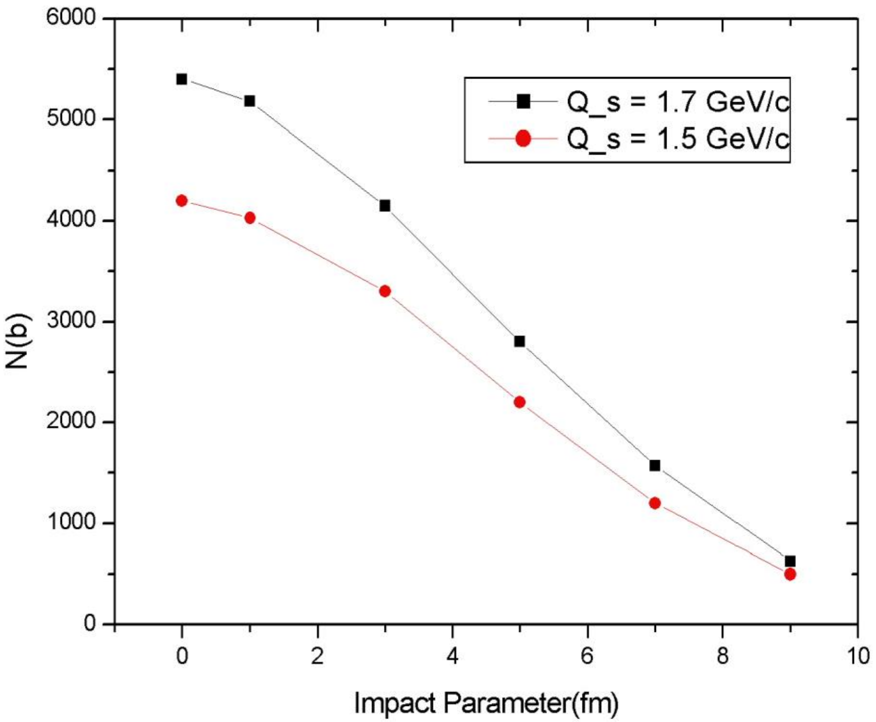
- Krasnitz, Nara and Venugopalan(KNV), Phys. Lett. B 554, 21 (2003); Nucl. Phys. A 717, 268 (2003).
- Lappi, Phys. Rev. C 67, 054903.

$$\frac{dN}{dy d^2 k_T} = \frac{\pi R^2}{g^2} f(k_T/\Lambda_s)$$

$$f = \frac{1}{g^2} \begin{pmatrix} a_1 [\exp(\sqrt{k_t^2 + m^2}/T_{eff}) - 1]^{-1}, k_t/\Lambda_s < 1.5 \\ a_2 \Lambda_s^4 \log(4\pi k_t/\Lambda_s) k_t^{-4}, k_t/\Lambda_s > 1.5 \end{pmatrix}$$

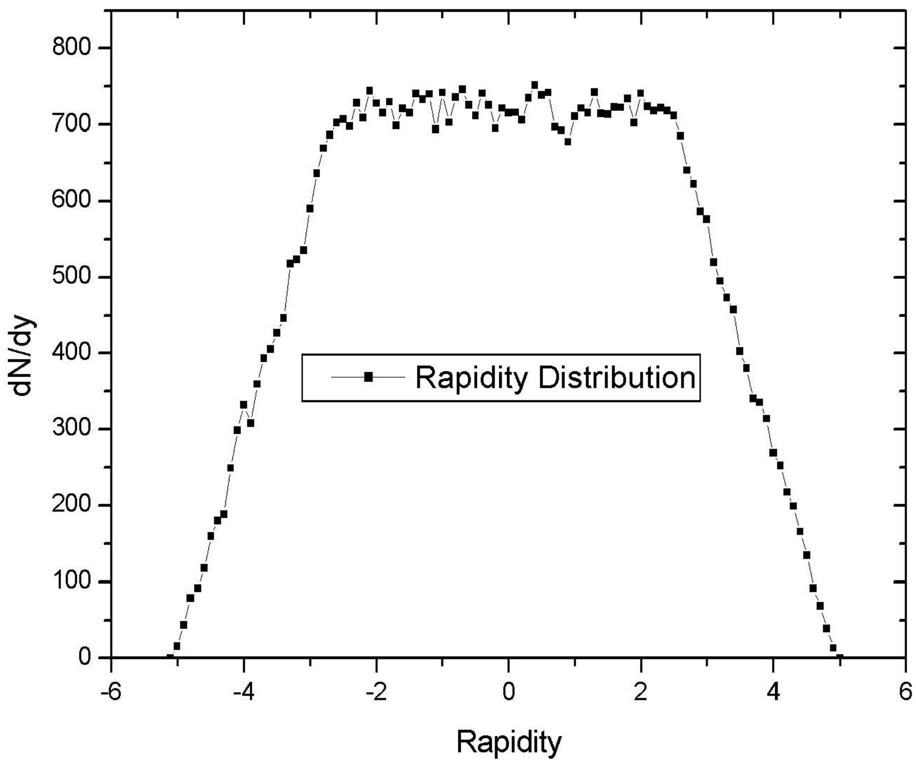
$$a_1 = 0.137, a_2 = 0.0087, m = 0.0358\Lambda_s, T_{eff} = 0.465\Lambda_s$$

- **Number of Partons:**



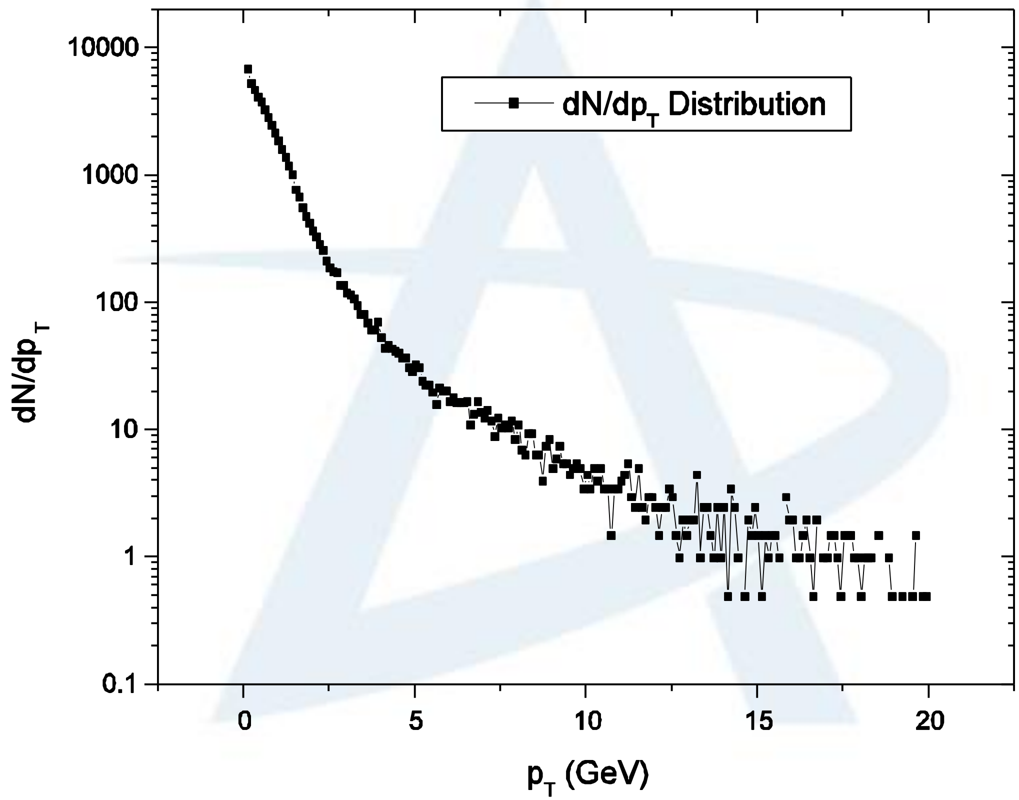
<Number of Partons produced:>

- **Initial rapidity distribution**：



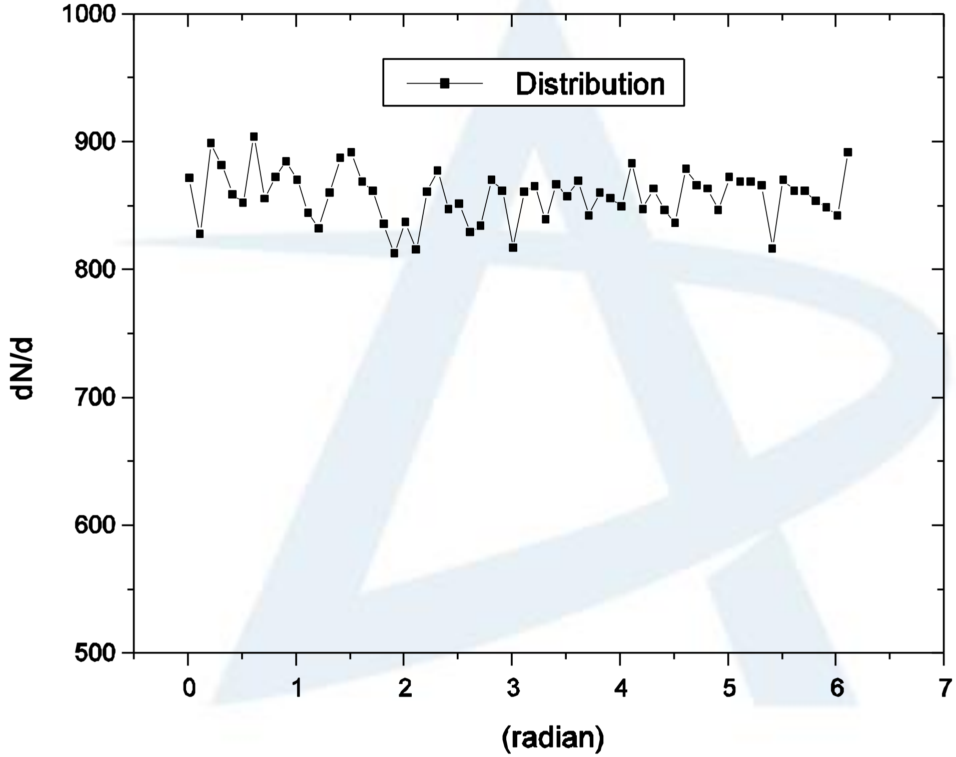
<Initial rapidity distribution of CGC: b=0fm>

- **Transverse momentum distribution**：

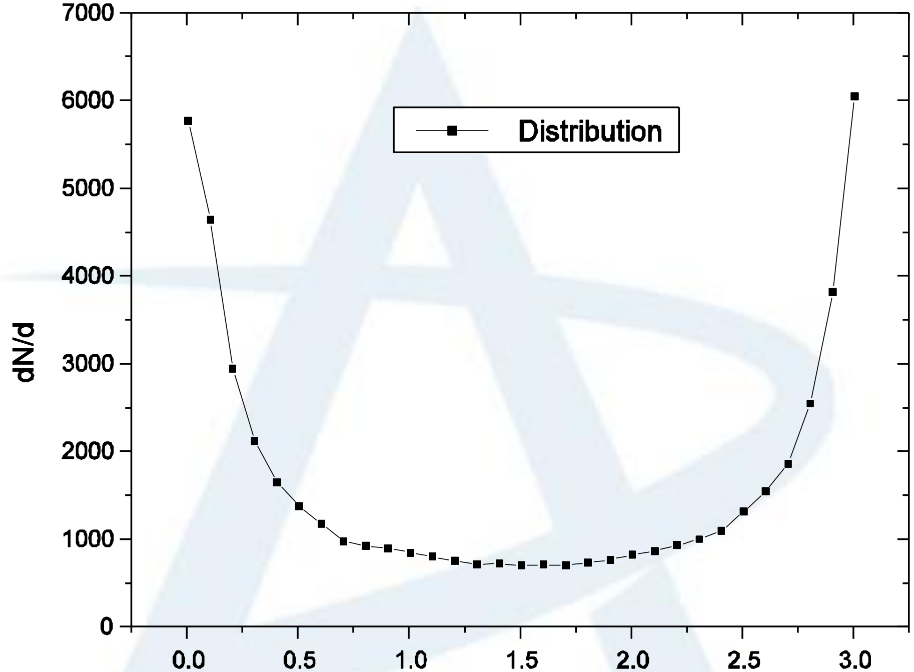


<Transverse momentum: b=0fm>

- **Azimuthal distribution**:



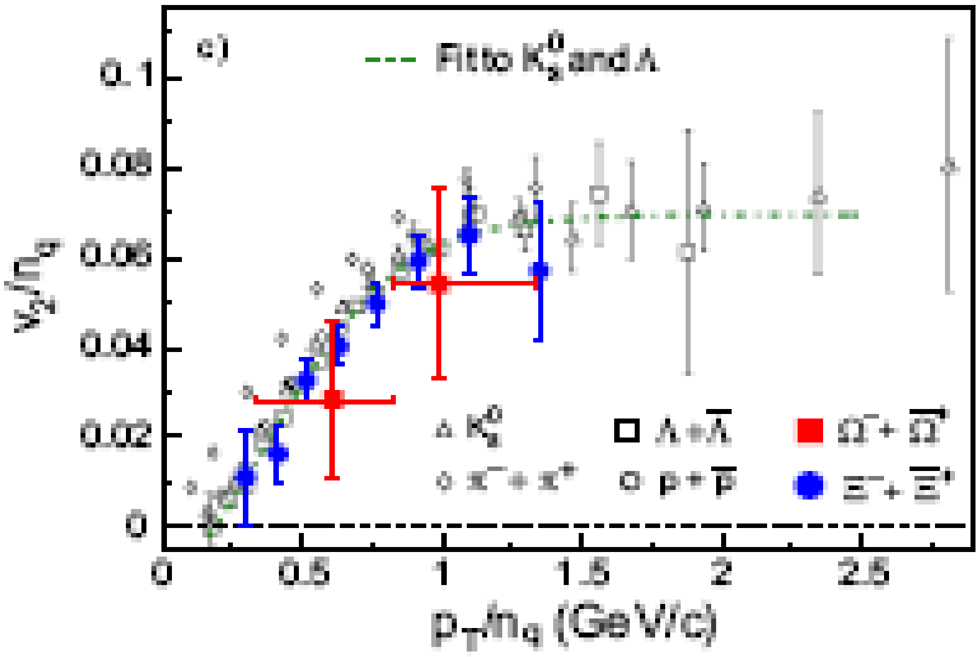
- **Polar angle distribution**:



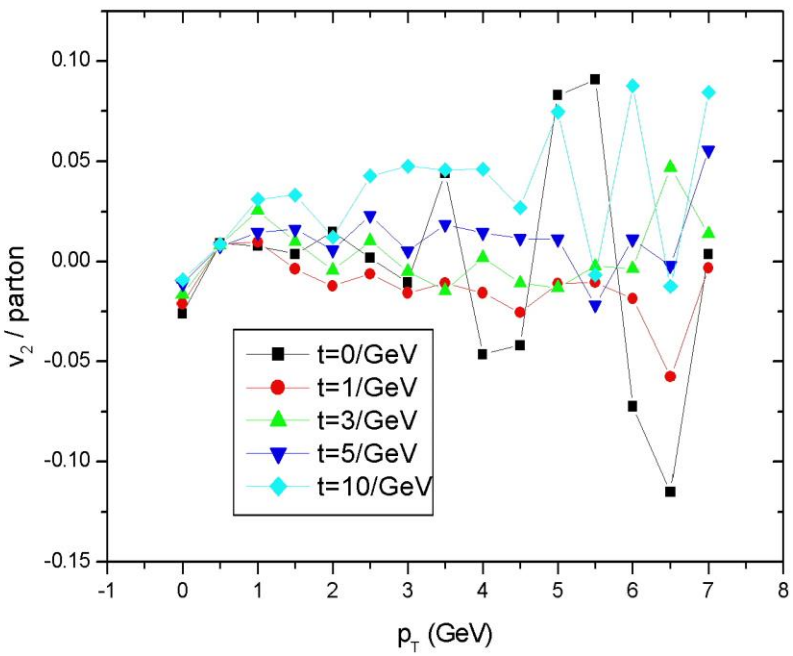
<Can see the strong orientation to collision axis: b=0fm>

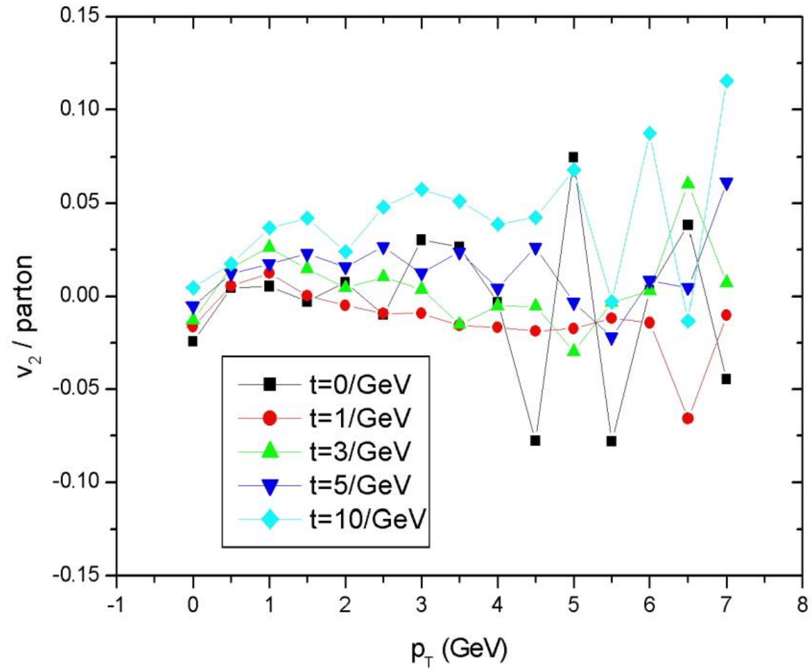
5. RESULTS

- **Elliptic Flow:**



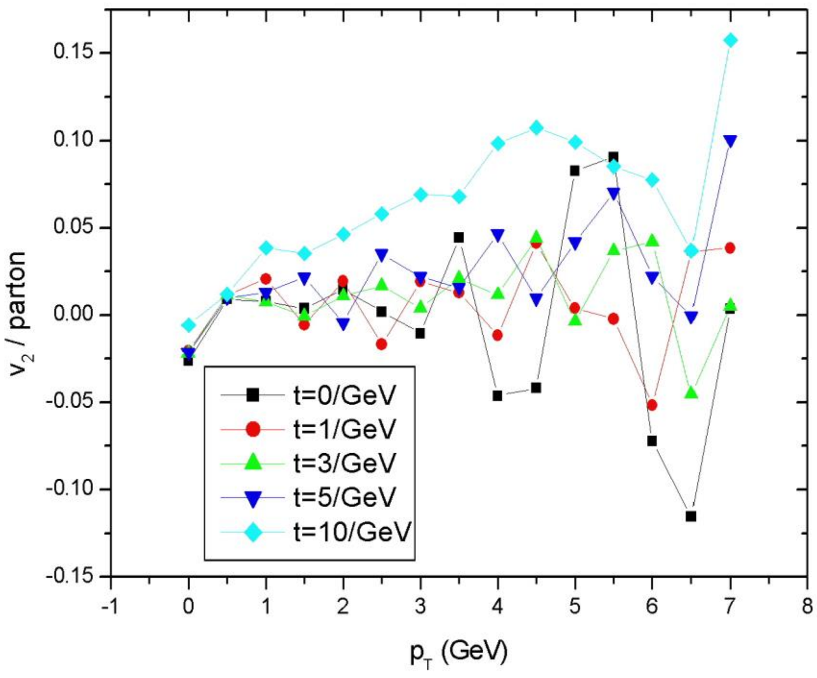
<from STAR:0501009>



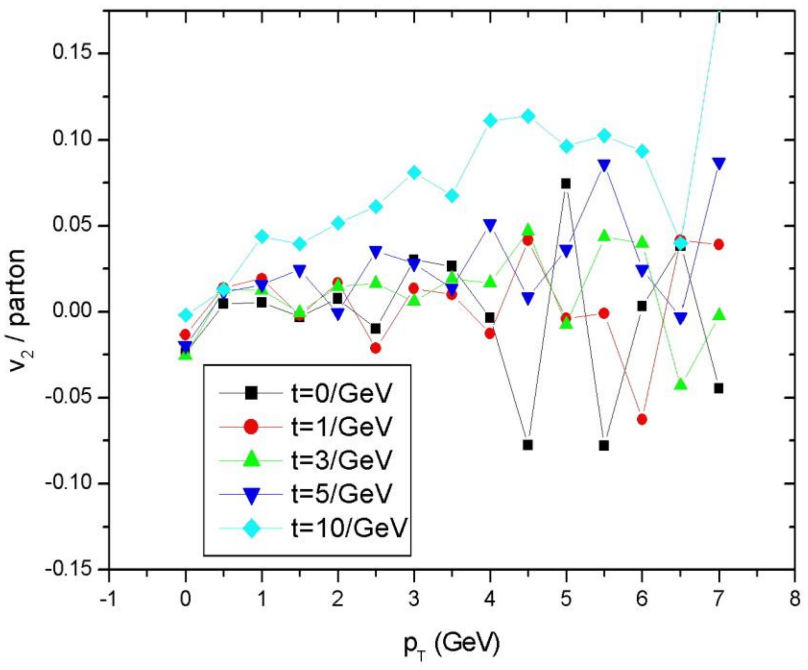


<b=7fm,K=2, LPM, all y >

<b=7fm,K=2, LPM, |y| < 2 >

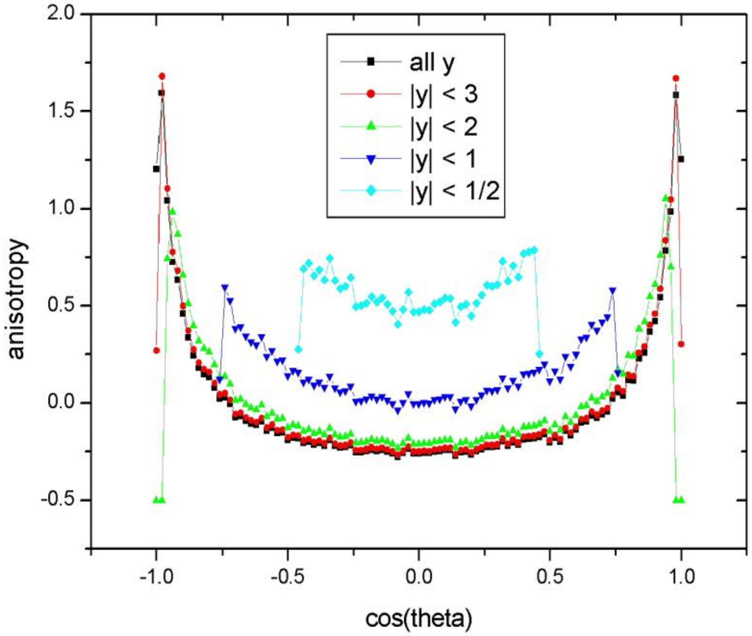


<b=7fm,K=4, LPM, all y >

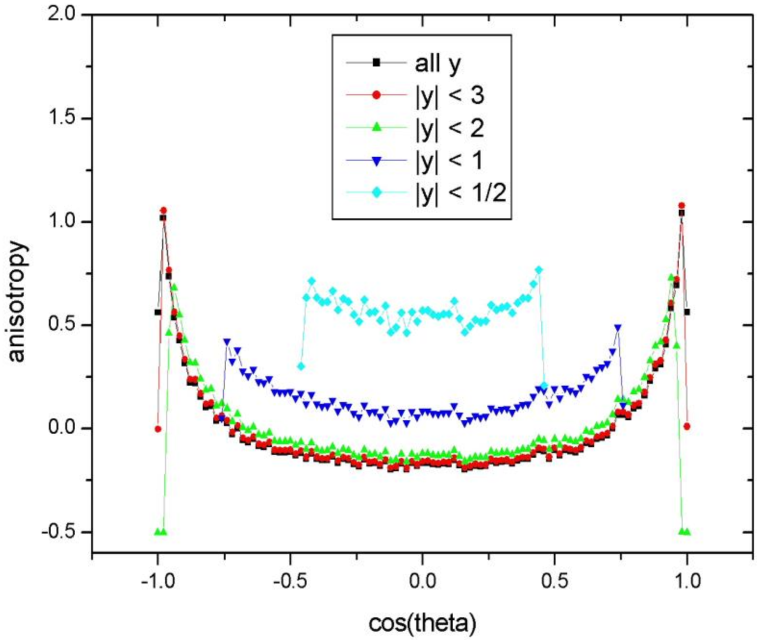


<b=7fm,K=4, LPM, |y| < 2 >

- **Polar Anisotropy**: $n(\theta, \phi) = \frac{1}{N_T}\frac{dN}{d\Omega} - \frac{1}{2}$

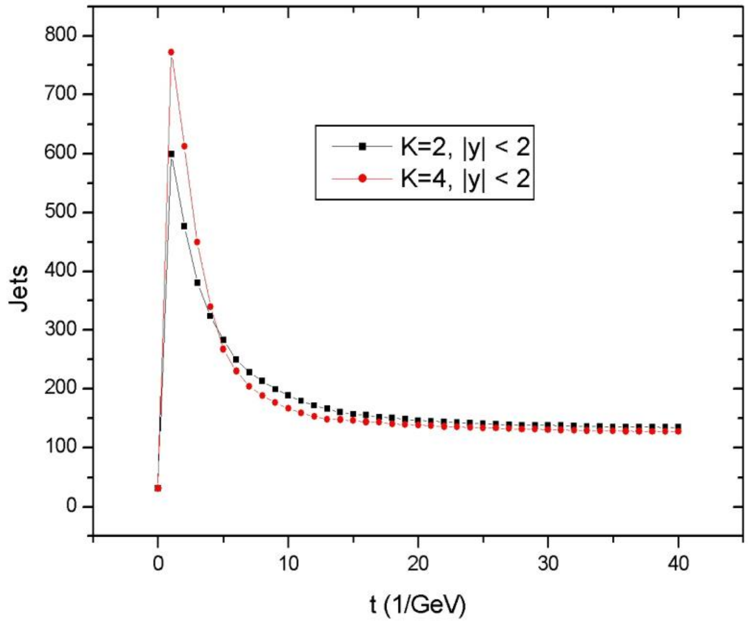


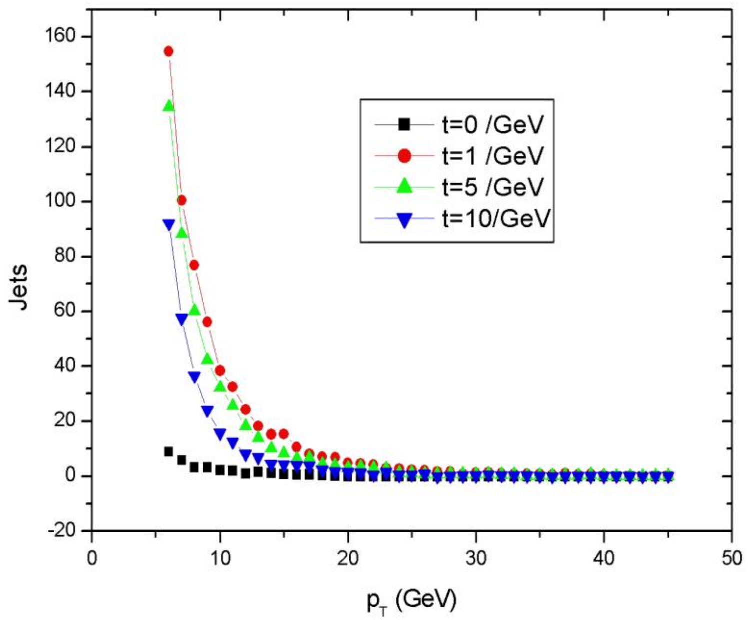
< b=0fm,K=2,LPM,t=3fm/c >



< b=0fm,K=4,LPM,t=3fm/c >

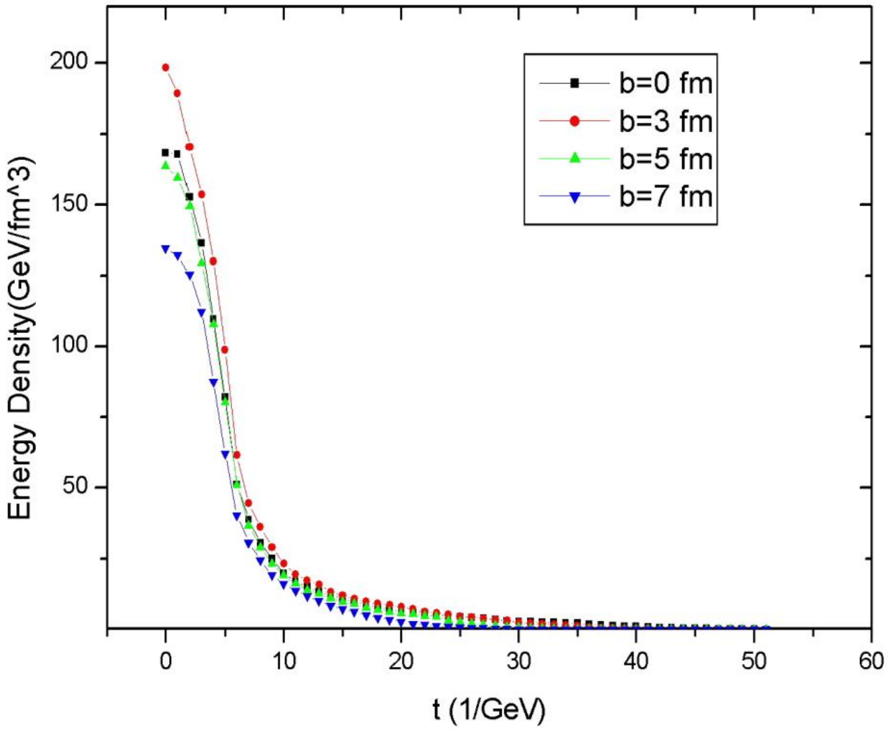
- **Number of JET and transverse distribution**：





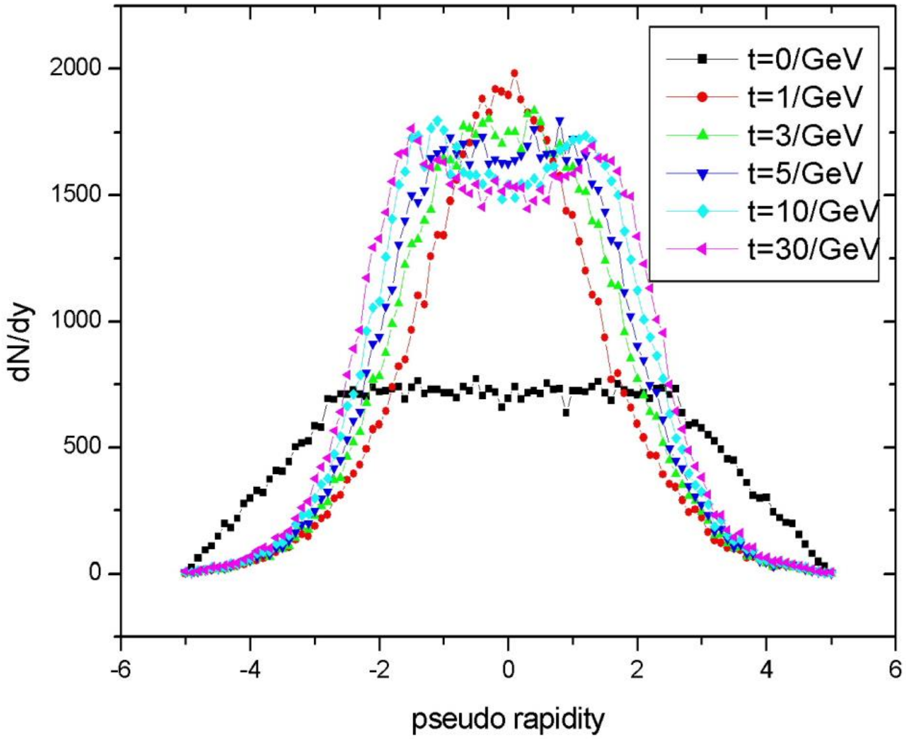
< b=0fm, K=2, LPM, |y|<2 >

- **Energy Density**



< K=2, LPM, at center with r=1.1fm >

- **Pseudo Rapidity Distribution**:



< K=2, LPM, b=0fm >

5. CONCLUSION

- **It seems to me that the elliptic flow can be understood without hydrodynamics**
- **There are many secondary JETS but lose energy**
- **Momentum isotropy(polar) cannot be achieved even with limited rapidity range**

- THANK YOU VERY MUCH!