Partonic effects on anisotropic flow in relativistic heavy ion collisions

Che-Ming Ko
Texas A&M University

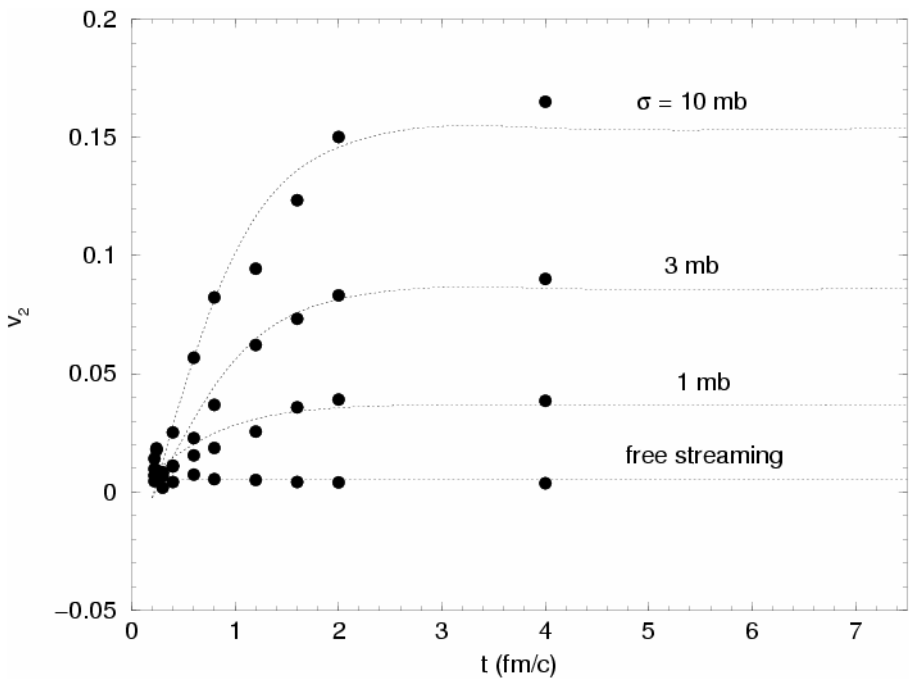
- Introduction
- A multi-phase transport (AMPT) model
- Anisotropic flow
  - Higher-order flow
  - Rapidity dependence
  - System size dependence
  - Flavor dependence
- Conclusions

Collaborators: Lie-wen Chen (SJTU)
Bin Zhang (Arkansas State Univ.)

Elliptic flow from parton cascade

Zhang, Gyulassy & Ko, PLB 455, 45 (1999)

Based on Zhang's parton cascade (ZPC) (CPC 109, 193 (1998))
using minijet partons from HIJING for Au+Au @ 200 AGeV and b=7.5fm



$$E\frac{d^3N}{d^3p}=\frac{1}{2\pi}\frac{dN}{p_T dp_T dy}\times\left[1+\sum_{n=1}^{\infty}2v_n(p_T,y)\cos(n\varphi)\right]$$

v_2 of partons is sensitive to their scattering cross section

Zhang's parton cascade (ZPC)

Bin Zhang, Comp. Phys. Comm. 109, 193 (1998)

$$p^{\mu}\partial_{\mu}f_1(x, p, t) \propto \int dp_2 d\Omega \, |\vec{v}_1 - \vec{v}_2| (d\sigma/d\Omega)(f_1' f_2' - f_1 f_2)$$

$$\frac{d\sigma}{dt} \approx \frac{9\pi\alpha_s^2}{2(t-\mu^2)^2}, \quad \sigma = \frac{9\pi\alpha_s^2}{2\mu^2}\frac{1}{1+\mu^2/s}$$

- Using α_s=0.5 and screening mass μ=gT≈0.6 GeV at T≈0.25 GeV, then $<s>^{1/2}$≈4.2T≈1 GeV, and pQCD gives σ≈2.5 mb and a transport cross section

$$\sigma_t \equiv \int d\Omega \frac{d\sigma}{d\Omega}(1 - \cos\theta) \approx 1.5\text{mb}$$

- σ=6 mb → μ≈0.44 GeV, σ_t≈2.7 mb
- σ=10 mb → μ≈0.35 GeV, σ_t≈3.6 mb

A multiphase transport model

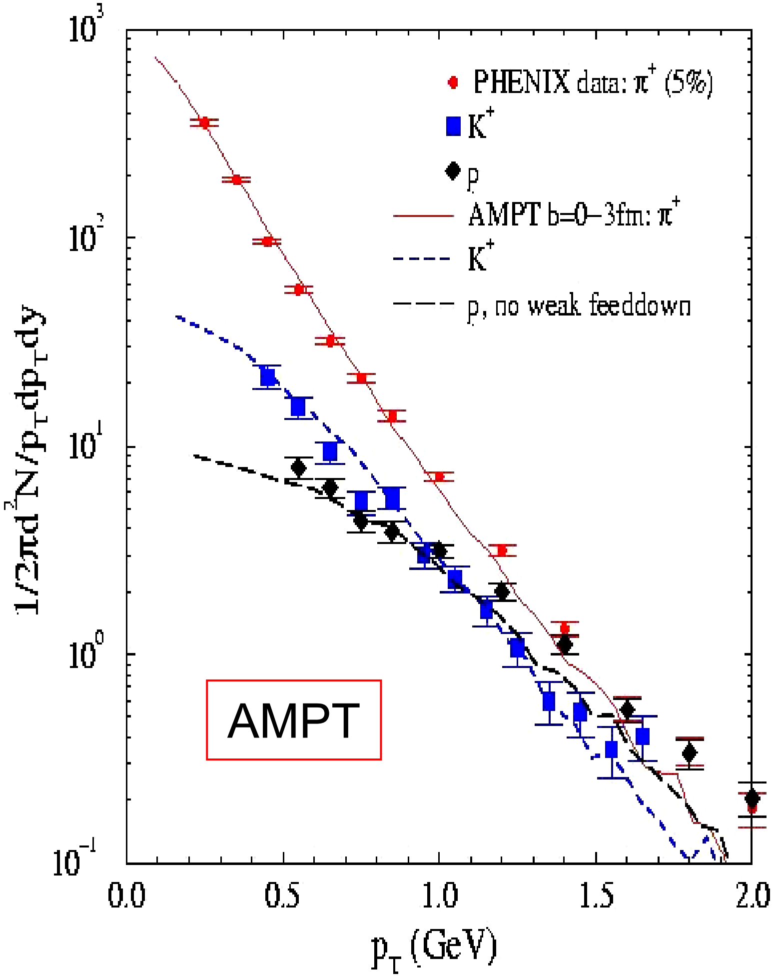
Default: Lin, Pal, Zhang, Li & Ko, PRC 61, 067901 (00);
64, 041901 (01); nucl-th/0411110

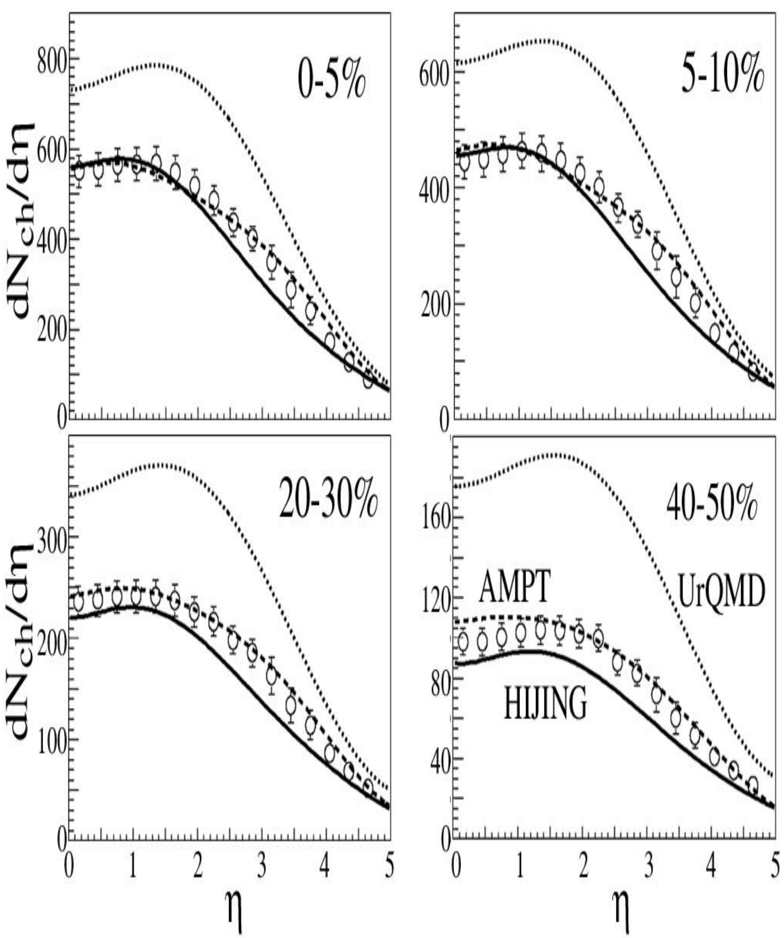
- Initial conditions: HIJING (soft strings and hard minijets)
- Parton evolution: ZPC
- Hadronization: Lund string model for default AMPT
  Coalescence model for string melting scenario
- Hadronic scattering: ART

String melting: PRC 65, 034904 (02); PRL 89, 152301 (02)

- Convert hadrons from string fragmentation into quarks and antiquarks
- Evolve quarks and antiquarks in ZPC
- When stop interacting, combine nearest quark and antiquark to meson, and nearest three quarks to baryon,
- Hadron flavors are determined by quarks' invariant mass

Transverse momentum and rapidity distributions

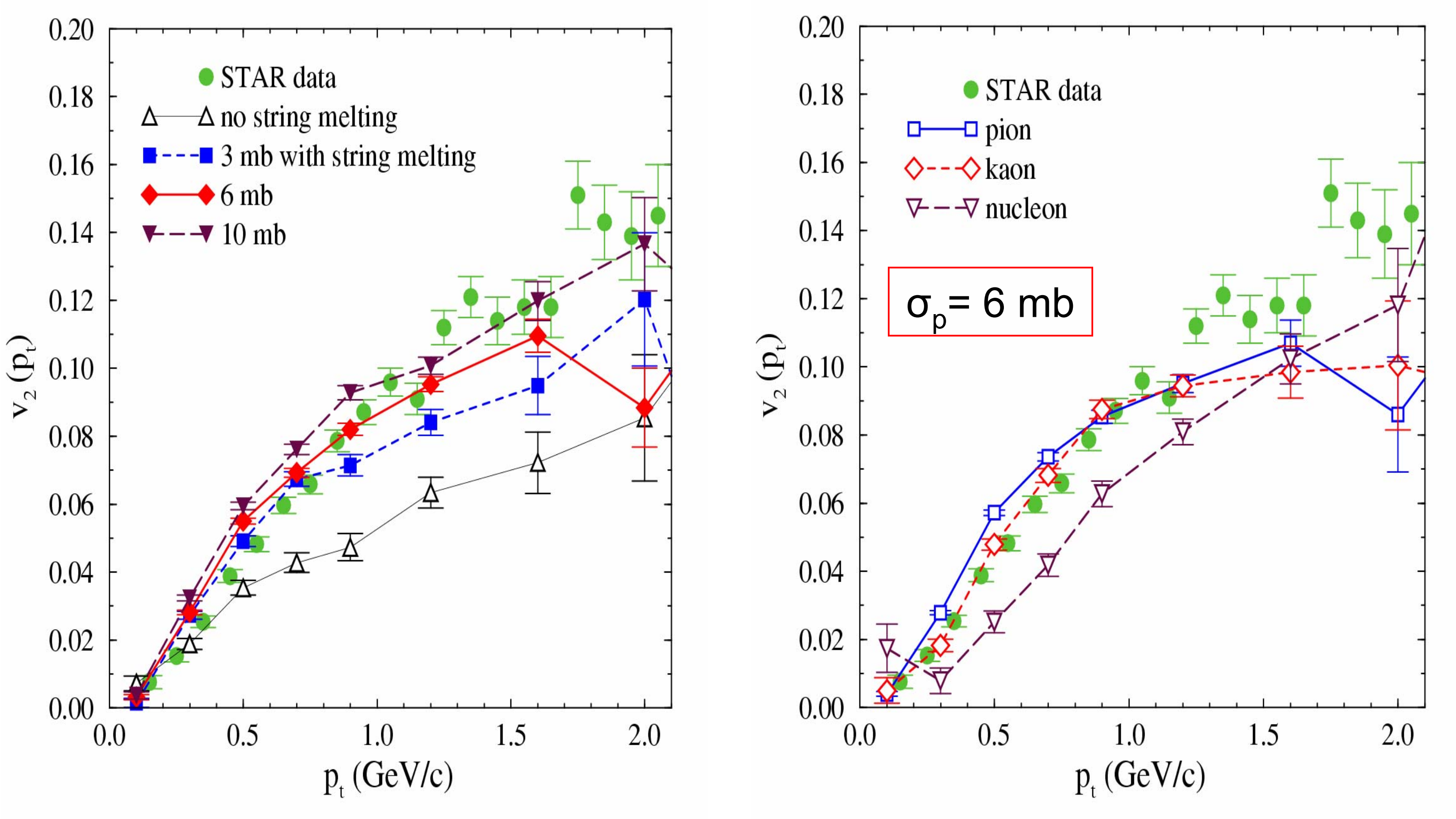




BRAHMS Au+Au @ 200 GeV

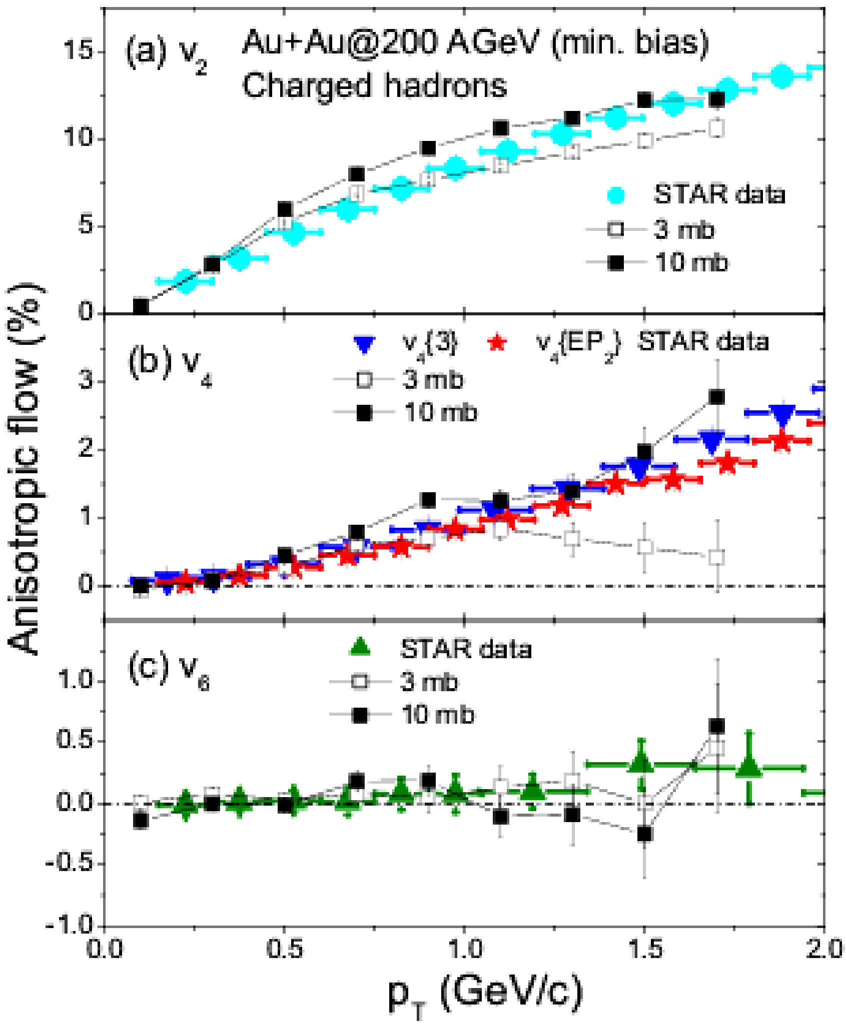
Elliptic flow from AMPT

Lin & Ko, PRC 65, 034904 (2002)

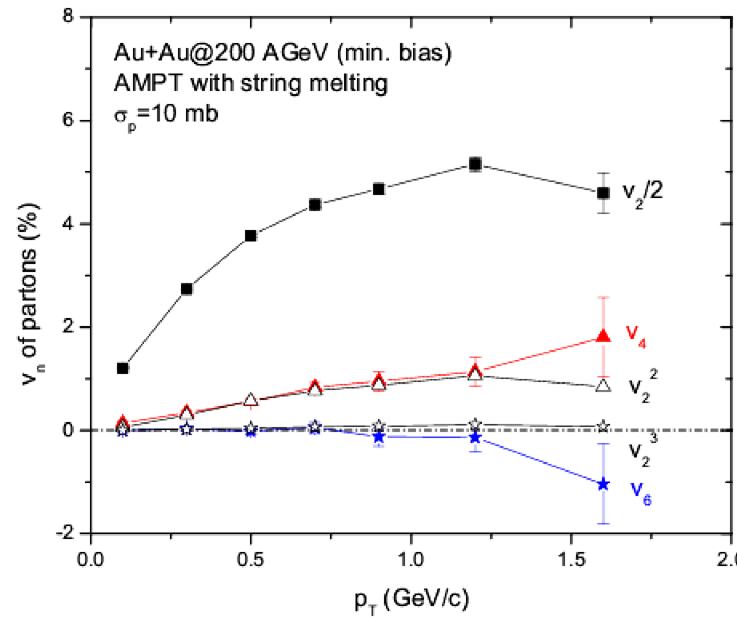


- Need string melting and large parton scattering cross section
- Mass ordering of v_2 at low p_T as in ideal hydrodynamic model

Higher-order anisotropic flow



Chen, Ko & Lin, PRC 69, 031901(R) (2004)

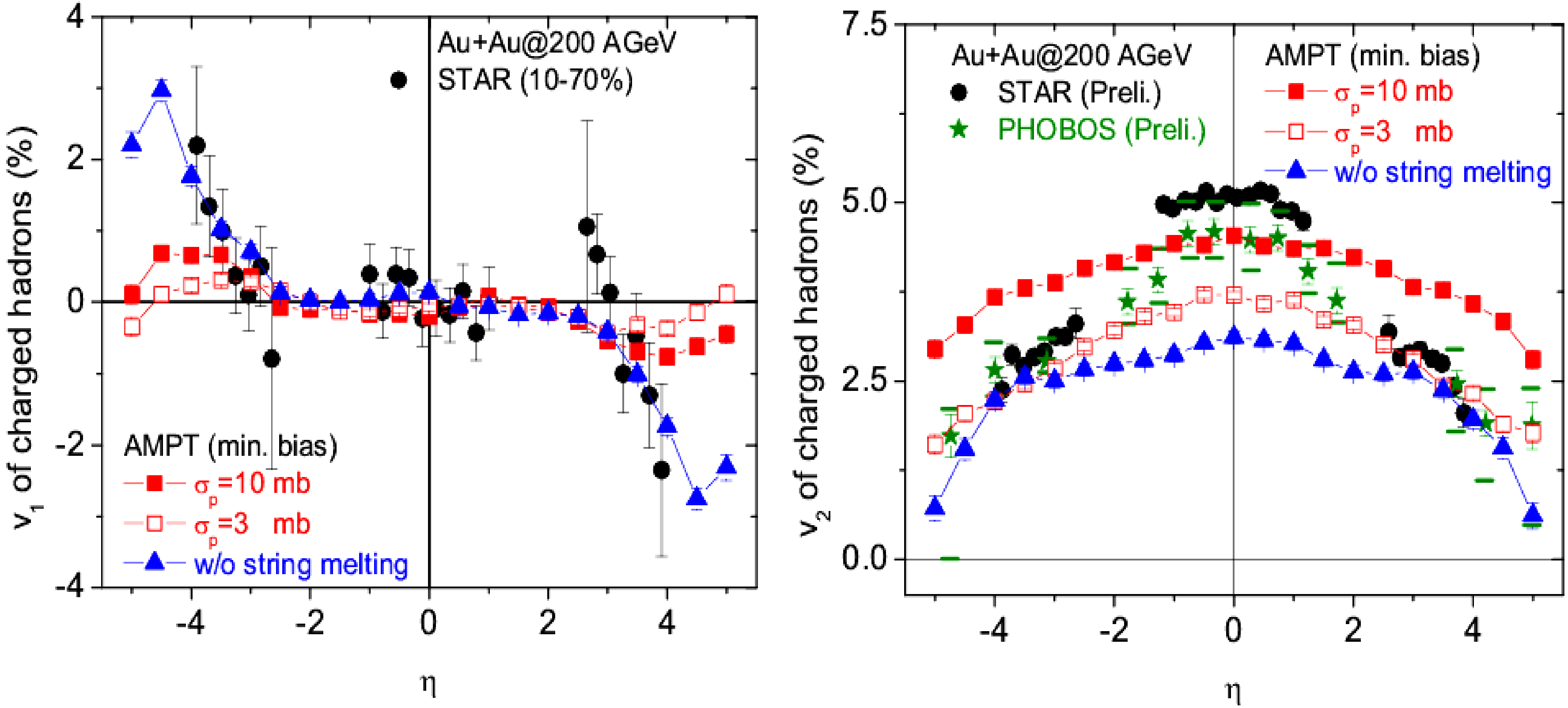


Parton cascade $v_{4,q} \approx v_{2,q}^2$

Data $\frac{v_4}{v_2^2} \approx 1.2 \Rightarrow v_{4,q} \approx 2v_{2,q}^2$ ← naïve coalescence model

Pseudorapidity dependence of v_1 and v_2

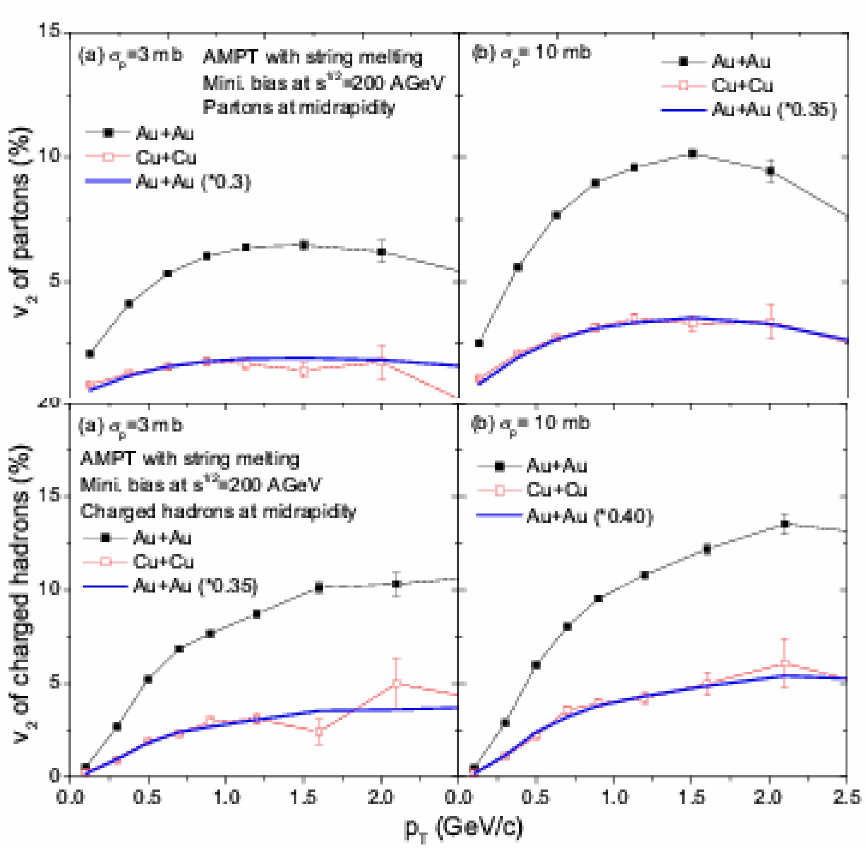
Chen, Greco, Ko & Koch, PLB 605, 95 (2005)



- String melting describes data near mid-rapidity ($|\eta|<1.5$)
- At large rapidity ($|\eta|>3$), hadronic picture works better

System size dependence of elliptic flow

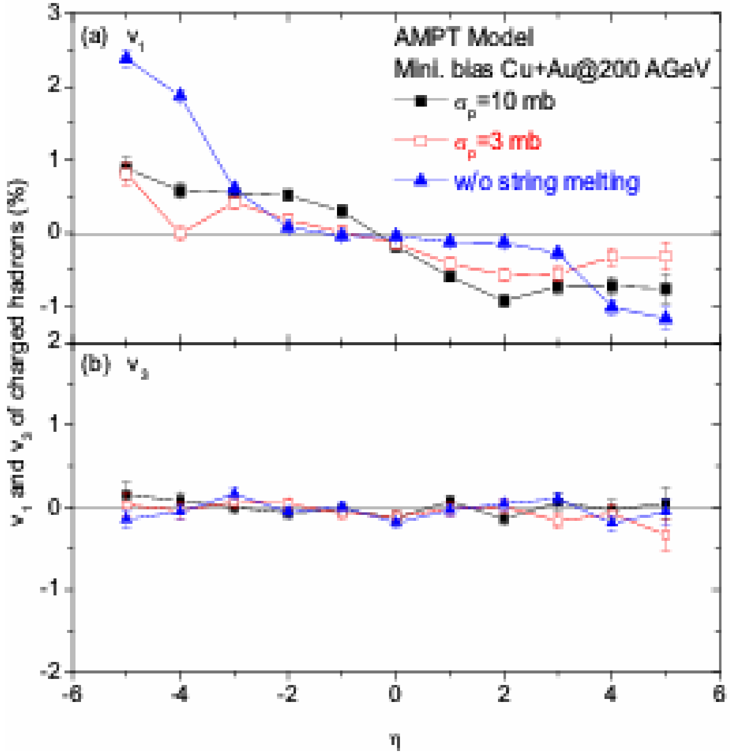
Chen & Ko, nucl-th/0505044

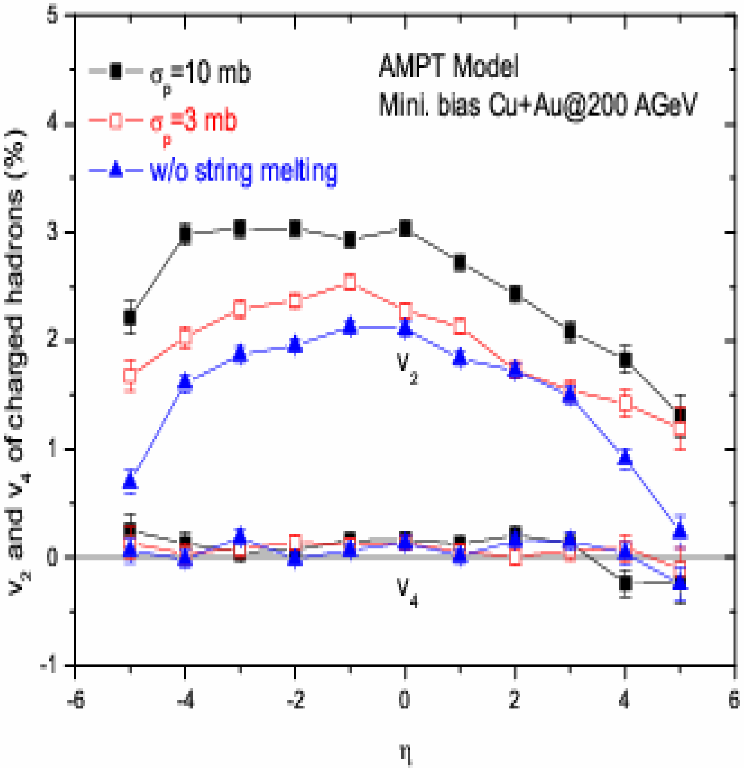


Ratio of elliptic flow is ~ 1/3 and scales with the size of colliding systems (~ product of ratios of initial eccentricity (~ ½) and energy density ~2/3)

Elliptic flow in collisions of asymmetric systems

Chen & Ko, nucl-th/0507067



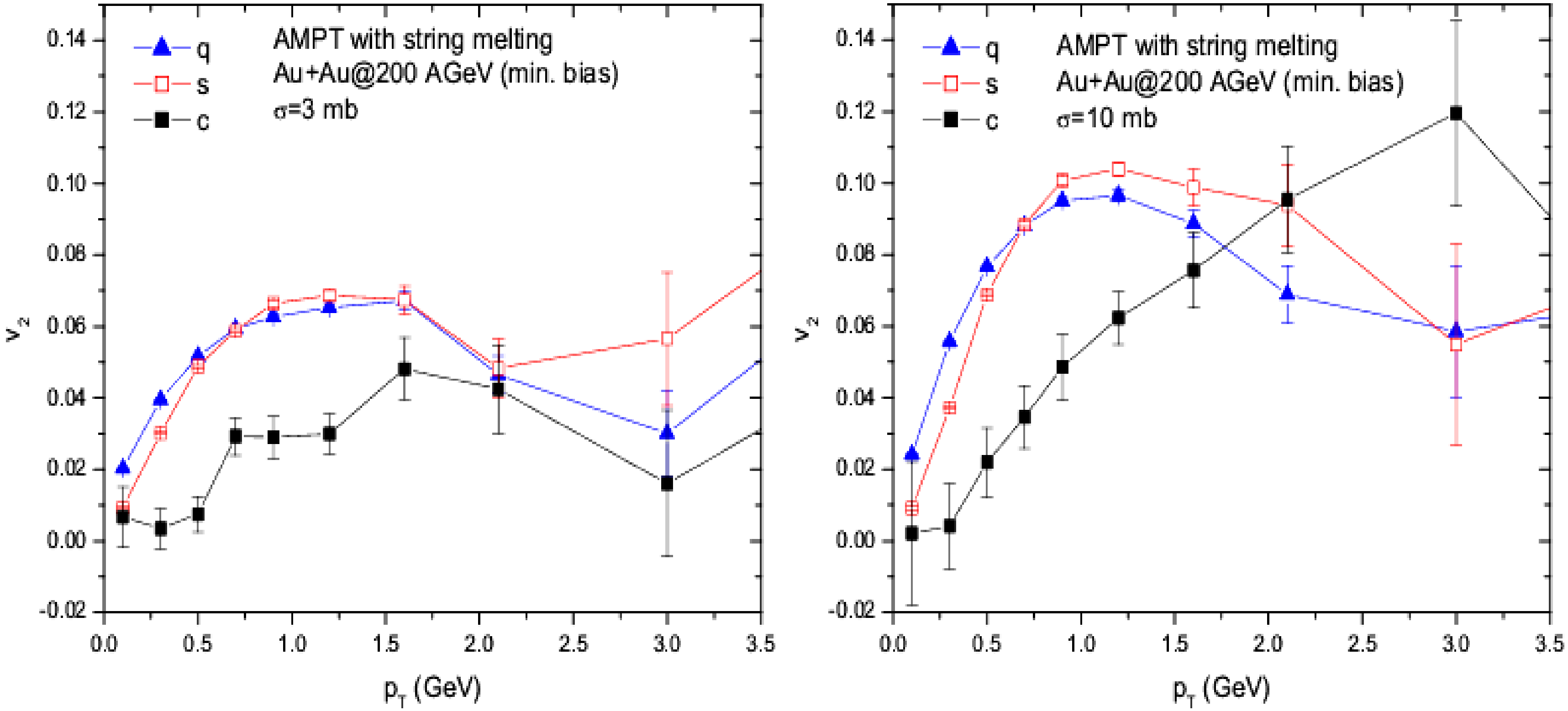


Compared to symmetric collisions

- Directed flow v_1 is stronger
- Elliptic flow v_2 is more sensitive to parton cross section
- Both directed and elliptic flows are asymmetric in forward and backward rapidities

Quark elliptic flows from AMPT

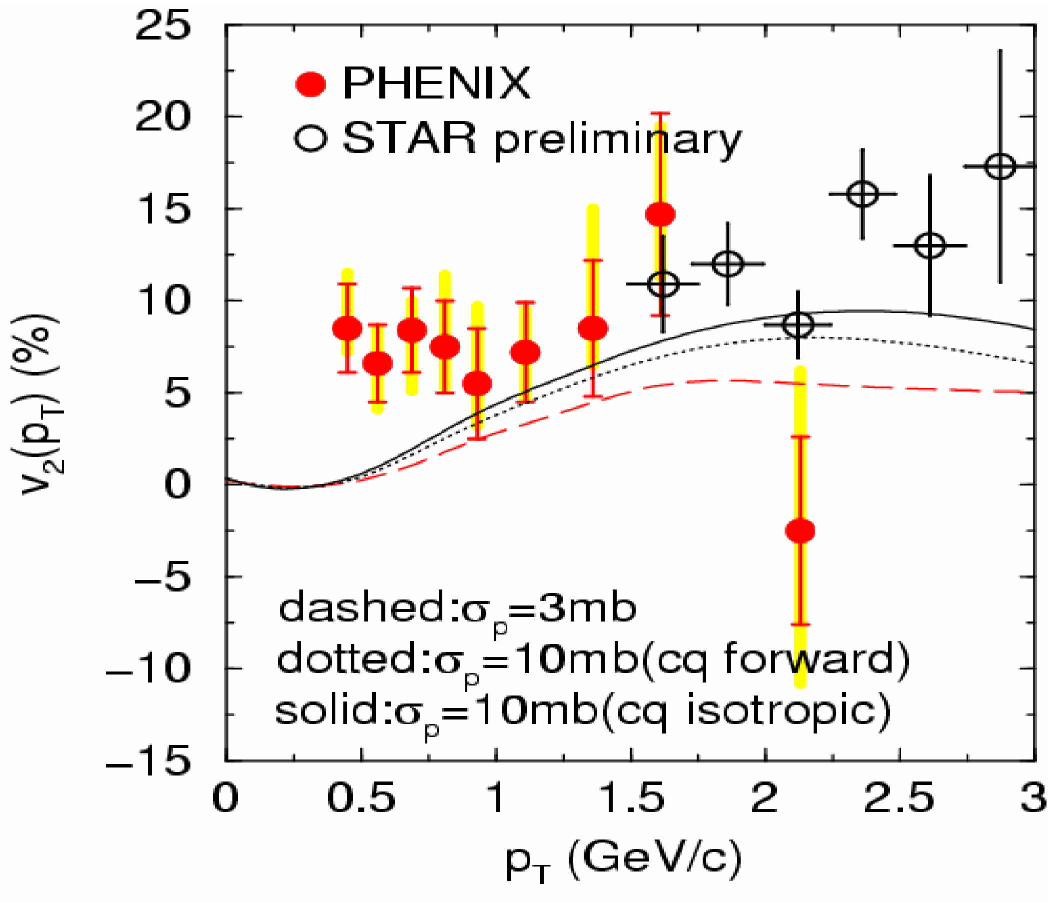
Zhang, Chen & Ko, nucl/th-0502056



- At high p_T, charm quark has similar v_2 as light quarks
- p_T dependence of charm quark v_2 is different from that of light quarks
- Charm quark v_2 is also sensitive to parton scattering cross sections

Charmed meson elliptic flow from AMPT

Zhang, Chen & Ko, nucl-th/0502056



Current light quark masses are used in AMPT. With constituent masses will enhance the charmed meson elliptic flow.

Conclusions

- Elliptic flow is sensitive to parton scattering cross section.
- The AMPT model with string melting reproduces observed large elliptic flow and mass ordering at low p_T with large parton cross section (quasi bound states in QGP and/or multiparton dynamics gg↔ggg?).
- Observed hadron $v_4 \approx 1.2 v_2^2$ is reproduced with parton $v_4 \approx v_2^{2.}$
- v_1 and v_2 at midrapidity requires formation of partonic matter, while those at large rapidity is consistent with a hadronic matter.
- AMPT predicts:
  - v_2 scales with the size of colliding system,
  - Stronger v_1 and more sensitivity of v_2 to parton cross section in asymmetric than symmetric collisions, and both show forward-backward asymmetry in rapidity.
- Observed large charmed meson flow requires larger charm quark scattering cross section (resonance effect?).