Considerations for Distinguishing Between Soft- and Hard-Component by Multiplicity Correlation

Na Li

Huazhong University of Science and Technology

7th International Workshop on CPOD,
7 - 11 November 2011

Motivation

Particle production

soft particles:
- from hot dense medium

jets:
- beginning of the collision
- hard process

Mixed when measured in experiment

➢ Particles produced in different processes carry different information of the collisions.

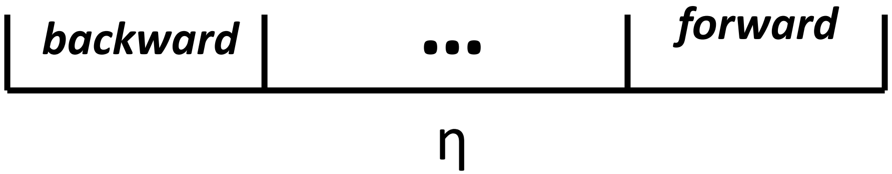
➢ It is important to distinguish the contribution of hydro part and non-hydro part, especially in the intermediate p_T region.

F-B Elliptic Correlation Function

Requirement: • Jet randomly falls into one region in a single event.

J. Liao and V. Koch, Phys. Rev. Lett. 103, 042302 (2009)

$$C_{FB} = \frac{\langle V_2^F V_2^B \rangle}{\langle V_2^F \rangle \langle V_2^B \rangle}$$



$$\frac{dM^B}{d\phi} = \left(\frac{1}{2} + \eta^B\right)\left\langle \frac{dM^f}{d\phi} \right\rangle + (1-\xi)\frac{dM^j}{d\phi} \qquad \frac{dM^F}{d\phi} = \left(\frac{1}{2} + \eta^F\right)\left\langle \frac{dM^f}{d\phi} \right\rangle + \xi\frac{dM^j}{d\phi}$$

Assumption:

• the multiplicity of flow particle in each side fluctuate independently -> $\langle \eta^F \eta^B \rangle = 0$

$$C_{FB} = \frac{(1-g)^2 \langle v_2^f \rangle^2 + 2g(1-g)\langle v_2^f \rangle \langle v_2^j \rangle}{\left[(1-g)\langle v_2^f \rangle + g\langle v_2^j \rangle\right]^2} \qquad g = \frac{M^j}{M^j + M^f}$$

g->0, (hydro dominance) C_{FB}->1

g->1, (jet dominance) C_{FB}->0

Unsolved Problem

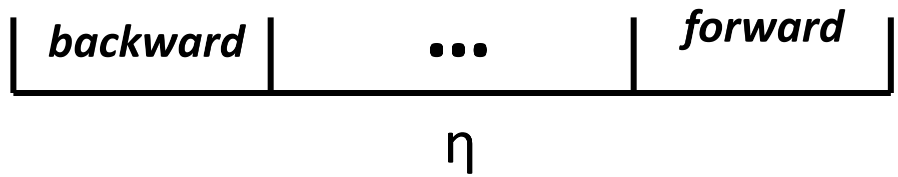
$$\begin{cases} C_{FB} = \dfrac{(1-g)^2 \left\langle v_2^f \right\rangle^2 + 2g(1-g)\left\langle v_2^f \right\rangle \left\langle v_2^j \right\rangle}{\left[(1-g)\left\langle v_2^f \right\rangle + g\left\langle v_2^j \right\rangle\right]^2} \\ \left\langle v_2 \right\rangle = (1-g)\left\langle v_2^f \right\rangle + g\left\langle v_2^j \right\rangle \end{cases}$$

2 equations with 3 unknown variables!

More measurement needed!

Multiplicity Correlation Function

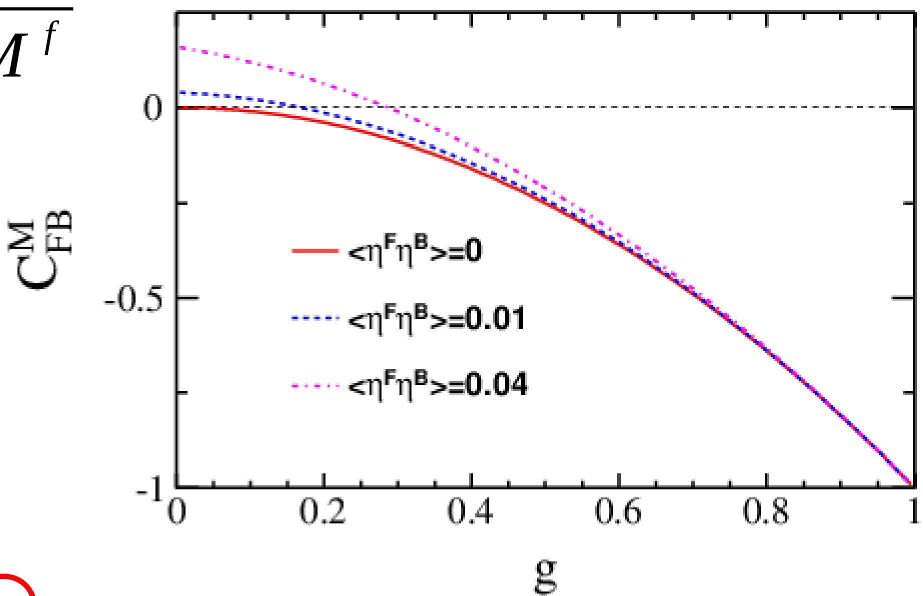
Definition:



$$C_{FB}^{M} = \frac{\langle M^{F} M^{B} \rangle}{\langle M^{F} \rangle \langle M^{B} \rangle} - 1 \qquad g = \frac{M^{j}}{M^{j} + M^{f}}$$

$$M^{F} = \left(\frac{1}{2} + \eta^{F} \right) \langle M^{f} \rangle + \xi M^{j}$$

$$M^{B} = \left(\frac{1}{2} + \eta^{B} \right) \langle M^{f} \rangle + (1 - \xi) M^{j}$$



$$C_{FB}^{M} = \underline{-g^{2}} + \underline{4 \langle \eta^{F} \eta^{B} \rangle (1 - g)^{2}}$$

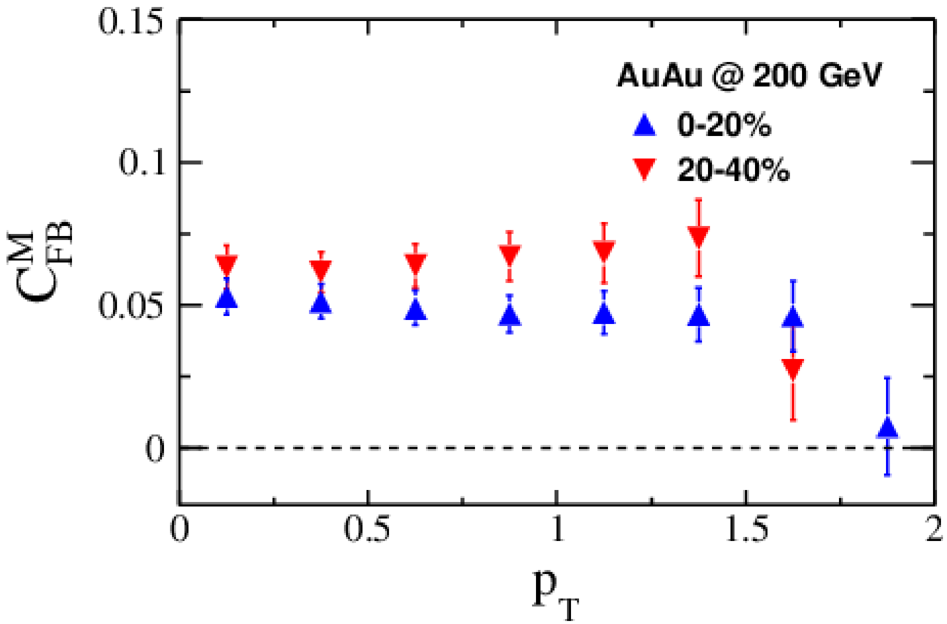
jet contribution FB correlation of flow multiplicity

- The effect of $\langle \eta^F \eta^B \rangle$ is small when g is relative large.

In A Multi-phase Transport Model (I)

AMPT string melting model

$$C_{FB}^{M} = -g^2 + 4\left\langle \eta^F \eta^B \right\rangle (1-g)^2$$



At low p_T :

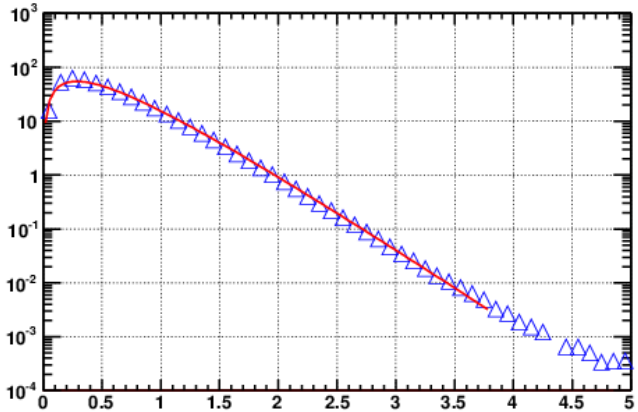
- With the assumption of no jet contribution at low p_T, we may obtain

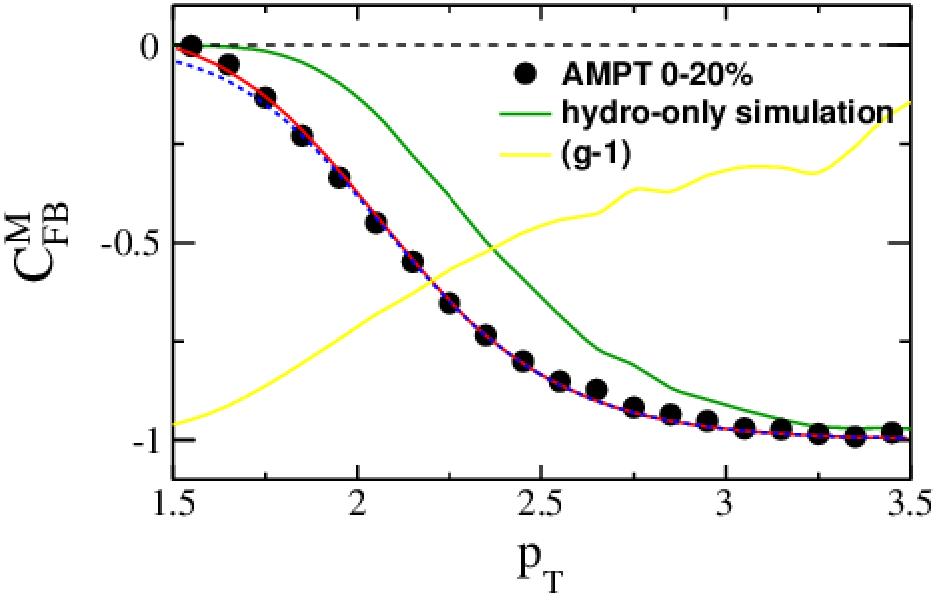
$$C_{FB}^{M} = 4\left\langle \eta^F \eta^B \right\rangle \approx 0.06$$

$$\left\langle \eta^F \eta^B \right\rangle \approx 0.0125$$

- Although the flow multiplicity exponentially decreases with p_T , little p_T dependence has been observed for $\langle \eta^F \eta^B \rangle$.

In A Multi-phase Transport Model (II)





At intermediate p_T :

- **The tail of hydro particle distribution may also caused the decreasing of FB multiplicity correlation function.**

- The data points from AMPT are lower than the hydro-only simulation.

- The jet contribution can not be neglect in intermediate p_T range.

Non-hydro Contribution in v_2

$$\langle v_2 \rangle = (1-g)\langle v_2^f \rangle + g\langle v_2^j \rangle \qquad C_{FB}^{V_2} = \frac{\langle V_2{}^F V_2{}^B \rangle}{\langle V_2{}^F \rangle \langle V_2{}^B \rangle}$$

If: the multiplicity of flow particle in each side fluctuate correlated $\langle \eta^F \eta^B \rangle \neq 0$

L. X. Han, Phys.Rev.C 83, 047901 (2011)

$$C_{FB}^{V_2} = \frac{(1-g)^2 \langle v_2^f \rangle^2 + 2g(1-g)\langle v_2^f \rangle \langle v_2^j \rangle}{\left[(1-g)\langle v_2^f \rangle + g\langle v_2^j \rangle\right]^2} + \frac{4\langle \eta^F \eta^B \rangle (1-g)^2 \langle v_2^f \rangle^2}{\left[(1-g)\langle v_2^f \rangle + g\langle v_2^j \rangle\right]^2}$$

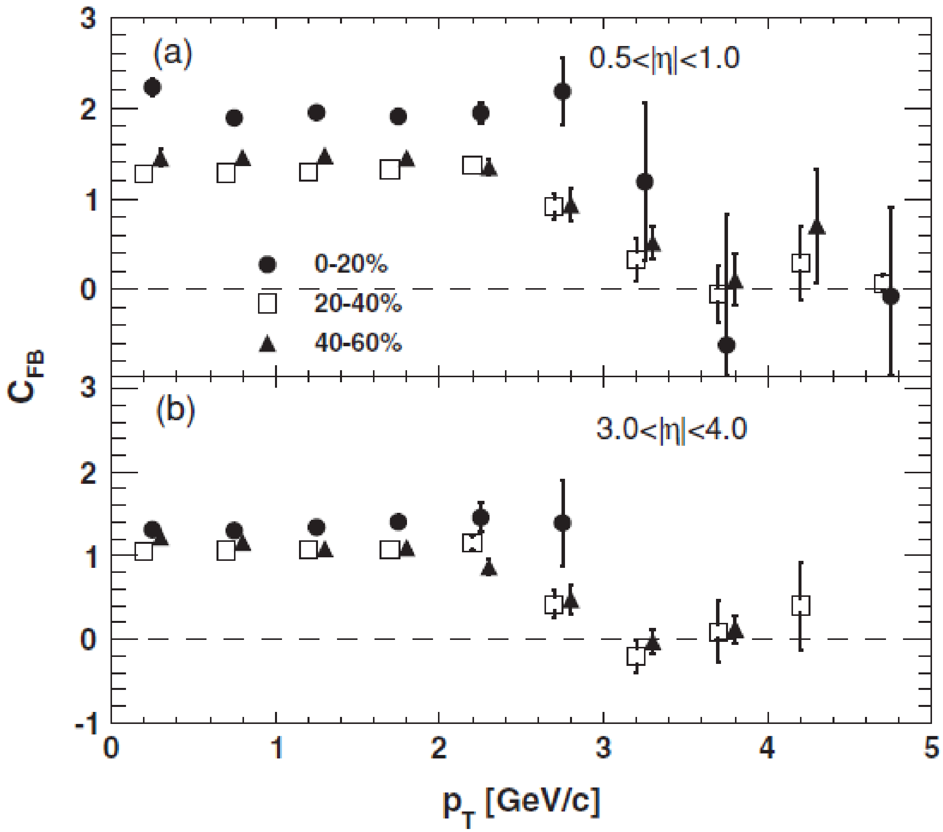
jet contribution

correlation of flow multiplicity fluctuation

Elliptic Correlation in AMPT

Results of AMPT model

L. X. Han, Phys.Rev.C 83, 047901 (2011)



- C_{FB} is about 2 in central collisions.
- $\langle \eta^F \eta^B \rangle$ is close to **0.25** at low p_T.

Inconsistent with the result from multiplicity correlation ?

$$\langle \eta^F \eta^B \rangle \approx 0.0125$$

v_2 fluctuation

$$\frac{dN^F}{d\phi} = \left(\frac{1}{2} + \eta^F\right)\left\langle \frac{dN^f}{d\phi} \right\rangle + \xi \frac{dN^j}{d\phi}$$

$$\frac{dN^B}{d\phi} = \left(\frac{1}{2} + \eta^B\right)\left\langle \frac{dN^f}{d\phi} \right\rangle + (1-\xi) \frac{dN^j}{d\phi}$$

Particles produced in in-plane and out-of-plane may fluctuate, thus η^F and η^B are the functions of ϕ, which may cause the fluctuation of v_2!

$$C_{FB}^{V_2} = \frac{(1-g)^2 \left\langle v_2^f \right\rangle^2 + 2g(1-g)\left\langle v_2^f \right\rangle \left\langle v_2^j \right\rangle}{\left[(1-g)\left\langle v_2^f \right\rangle + g\left\langle v_2^j \right\rangle\right]^2} + \frac{4(1-g)^2 \sigma_{v_2}^{f\,2}}{\left[(1-g)\left\langle v_2^f \right\rangle + g\left\langle v_2^j \right\rangle\right]^2}$$

For the flow dominate case: $g \rightarrow 0 \quad C_{FB}^{V_2} \approx 4\frac{\sigma_{v_2}^{f\,2}}{\left\langle v_2 \right\rangle^2} > 1$

➢ Larger v_2 fluctuation in central collision causes the larger C_{FB} at low p_T.

Observables

$$\left\{\begin{aligned} C_{FB}^{V_2} &= \frac{g^2\left\langle v_2^j\right\rangle^2}{\left\langle v_2\right\rangle^2} + \frac{4(1-g)^2\sigma_{v_2}^{f\,2}}{\left\langle v_2\right\rangle^2} \\ \left\langle v_2\right\rangle &= (1-g)\left\langle v_2^f\right\rangle + g\left\langle v_2^j\right\rangle \\ C_{FB}^{M} &= -g^2 + 4\left\langle \eta^F\eta^B\right\rangle(1-g)^2 \end{aligned}\right.$$

$$C_{FB} = \frac{\left\langle X^F X^B\right\rangle}{\left\langle X^F\right\rangle\left\langle X^B\right\rangle} - 1$$

- Constant at low p_T
- Neglectable at large g

Pure flow and jet v_2 are expected to be extracted!

Summary

- A multiplicity correlation is proposed to measure non-hydro contribution.

- The forward-backward multiplicity correlation $\langle \eta^F \eta^B \rangle$ is small in the transport model.

- The jet contribution is significant in intermediate p_T.

- The elliptic anisotropy correlation is proposed to measure the non-collective contribution from elliptic flow.

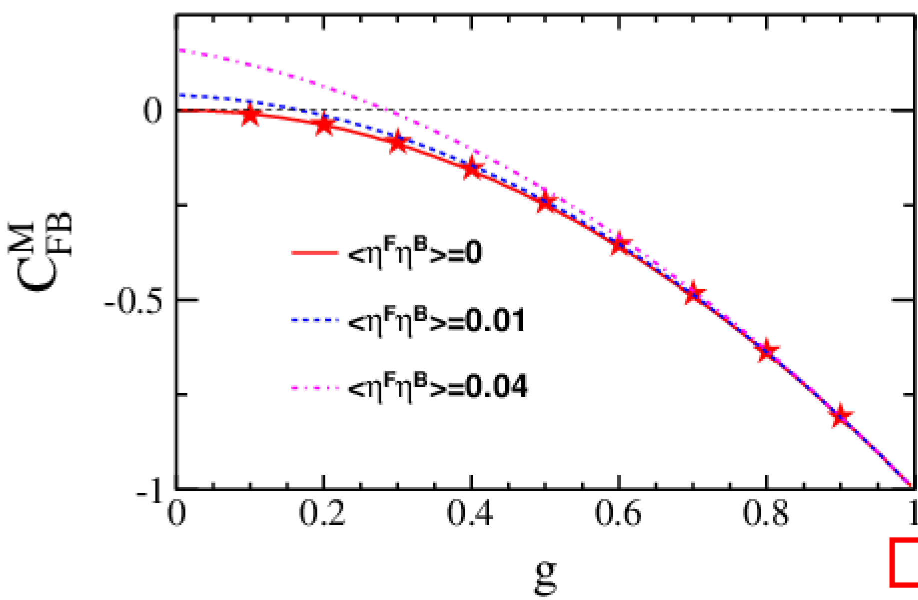
Thank You!

Multiplicity Correlation Simulation

Inputs:

- M^{flow} and M^{jet} are constrained by *g*
- (M^{flow} +M^{jet}) fluctuates ±20%
- ϕ^{flow} randomly generated between [0, 2π]
- ϕ^{jet} randomly generated between [0, 2π] , and associated particles are generated within ±π/16 according to jet direction

$$C_{FB}^{M} = -g^2 + 4\langle \eta^F \eta^B \rangle (1-g)^2$$



➢The effect of <ηFηB> is small when g is relative large.

➢ **C_{FB}** is consistent with the theoretical value.

➢ The method is not very sensitive with the pure multiplicity fluctuation.

No correlation in the simulation

Real case?

Non-hydro Contribution in v_2

$$\langle v_2 \rangle = (1-g)\langle v_2^f \rangle + g\langle v_2^j \rangle$$

$$C_{FB}^{V_2} = \frac{\langle V_2^F V_2^B \rangle}{\langle V_2^F \rangle \langle V_2^B \rangle} - 1$$

If: the multiplicity of flow particle in each side fluctuate correlated

$$\langle \eta^F \eta^B \rangle \neq 0$$

L. X. Han, Phys.Rev.C 83, 047901 (2011)

$$C_{FB}^{V_2} = \frac{g^2 \langle v_2^j \rangle^2}{\langle v_2 \rangle^2} + \frac{4\langle \eta^F \eta^B \rangle (1-g)^2 \langle v_2^f \rangle^2}{\left[(1-g)\langle v_2^f \rangle + g\langle v_2^j \rangle\right]^2}$$

jet contribution

correlation of flow multiplicity fluctuation

Elliptic Correlation Simulation

Inputs:

- N^{flow} and N^{jet} are constrained by *g*
- $(N^{flow} + N^{jet})$ fluctuates ±20%

Add in v_2 signal

$$\tilde{v}_2^{flow} = 0.12$$

$$\tilde{v}_2^{jet} = 0.07$$

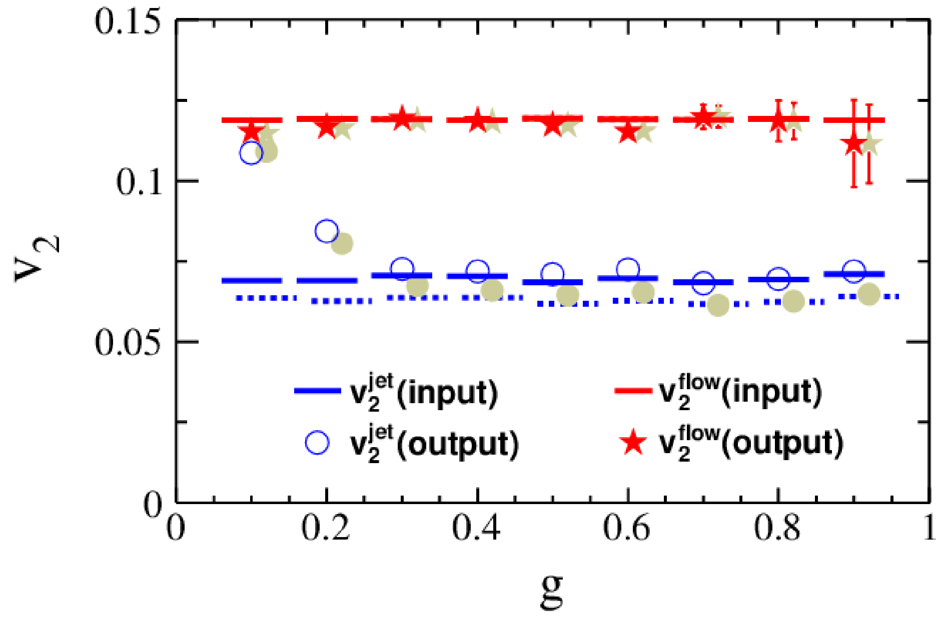
A. M. Poskanzer, Phys.Rev.C 58, 1671(1998)

$$\phi \rightarrow \phi' = \phi + \Delta\phi$$

$$\Delta\phi = \sum_n \frac{-2}{n} \tilde{v}_n \sin\left[n(\phi - \psi_0)\right]$$

- Associated particles are generated within ±π/8
- according to jet direction

grey markers: jet corn = π/4



➢ The pure jet elliptic anisotropy v_2 could be extracted from when $g \geq 0.3$